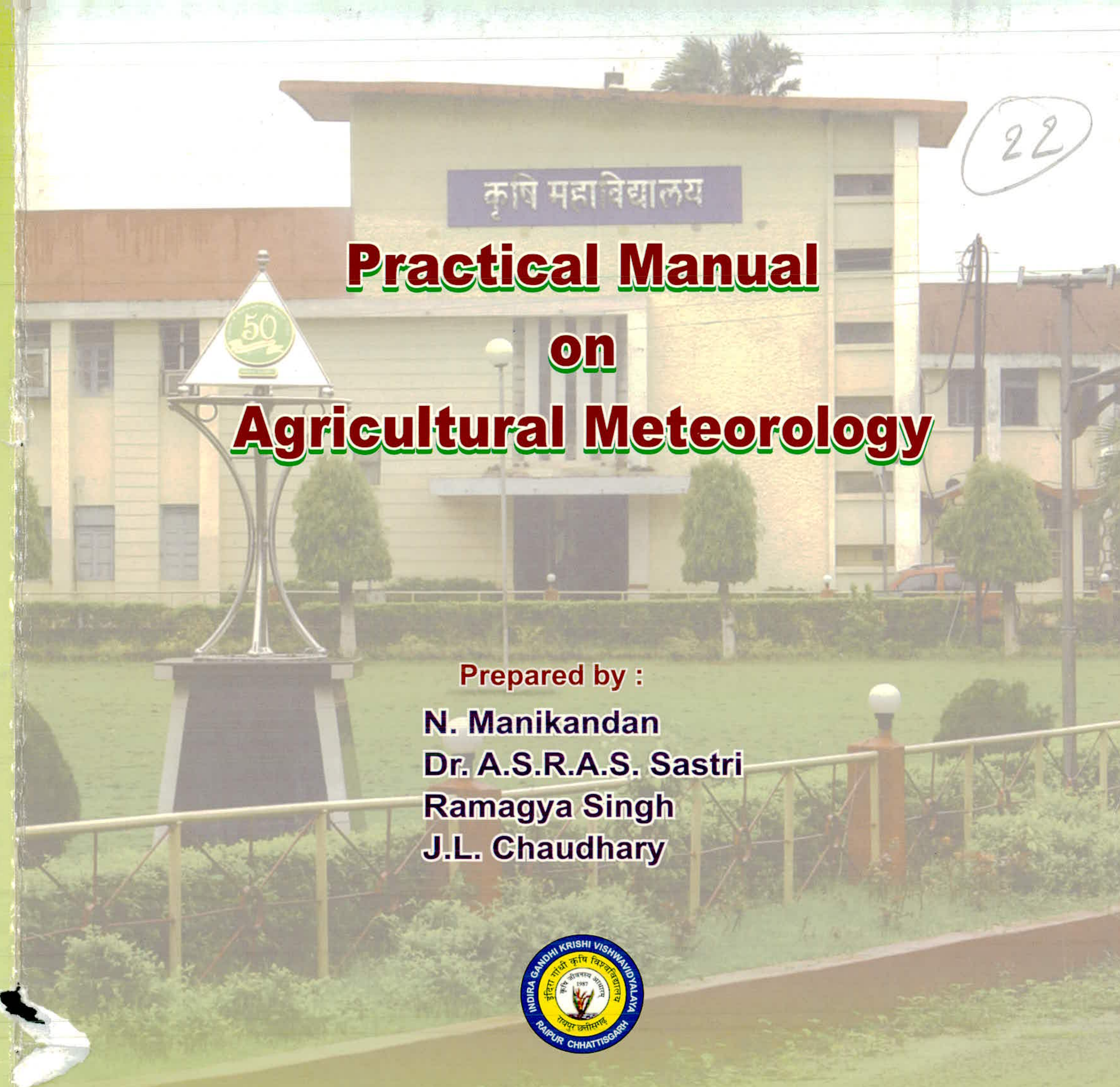

Practical Manual
on
Agricultural Meteorology

Prepared by :

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Date: Course Teacher

Content

Practical No. 1

Title: **Visit to an Agricultural Meteorological Observatory**
Objective: **To acquaint the students about the layout and establishment of agromet observatory**

In agricultural meteorology, the weather / climatic variables are recorded to assist the management of agricultural activities. Such management includes determining the timing of agricultural operations like ploughing, harrowing, sowing / planting, application of insecticides and herbicides, irrigation, harvesting and also for transport of agricultural products. In addition to the above mentioned, for precise investigation and quantification of relationships between weather variables and crop production detailed observations on crop growth and development along with regular observations of weather variables are necessary.

The meteorological elements of importance to agriculture are rainfall, air temperature, soil temperature, air humidity, evaporation / evapotranspiration, soil moisture, radiation / sunshine duration, cloudiness, dew, wind speed. Due attention should be given to record the occurrence of abnormal weather phenomena like thunderstorms, hailstorms, frost, heavy winds, droughts and floods which are affecting the agricultural production.

Observatory: It is a place where several instruments are kept to observe/record the various meteorological elements at stipulated time.

Site selection criteria for agro-meteorological observatory:

- It should it be regionally representative.
- The site should be well exposed, bare levelled plot having the length of 55 m in north-south direction and the width of 36 m in east-west direction.
- It should represent the natural soil topography and under no circumstances it should have concrete, asphalt, or crushed rock layers. Wherever the local climate and soil do not permit a grass cover, the ground should have natural cover common to the area, to the extent possible.
- It should be located more or less at the centre of the research farm.
- The site should be well away from the high hills, buildings, trees, structures, main irrigation canals, water tanks etc., Under unavoidable circumstances, site may selected in such way that the distance should be more than ten times of the instruments height.

- The site should be free from water logging and easily accessible during the rainy season too.
- It should be protected from entry of animals by proper enclosing with barbed wire fencing in order to provide safety to meteorological instruments and to avoid disturbance to observations.

Fig.1.1. Layout plan for Principal agro-meteorological observatory

N

Border			5m
	Sunshine recorder		9m
Wind vane	Pyranometer	Anemometer	9m
Single Stevenson's screen		Double Stevenson's screen	9m
Ordinary Rain gauge	Dew gauge	Self recording rain gauge	9m
Soil thermometer	Open pan evaporimeter	Grass minimum thermometer	9m
Border			5m
12m	12m	12m	

Essential and optional instruments for different observatories

Depending upon the availability of the instruments and the number of weather elements observed the agro-meteorological observatories fall into four groups *viz.,* principal, ordinary, auxiliary and specific purpose observatories. The essential and optional instruments required for these types are also given in the table 1.1.

Table.1.1. Types of observatories and corresponding list of instruments

S.No	Principal	Ordinary	Auxiliary
		A. Essential Instruments	
1	Wet & dry bulb thermometer	Wet & dry bulb thermometer	Wet & dry bulb thermometer
2	Maximum & minimum thermometer	Maximum & minimum thermometer	Maximum & minimum thermometer
3	Soil thermometer	Soil thermometer	Ordinary rain gauge
4	Grass minimum thermometer	Grass minimum thermometer	
5	Ordinary & self recording rain gauges	Ordinary rain gauge	
6	Wind vane & anemometer	Wind vane & anemometer	
7	USWB open pan evaporimeter	USWB open pan evaporimeter	
8	Assmann psychrometer	Assmann psychrometer	
9	Sunshine recorder		
10	Dew gauge		
11	Thermo-hygrograph		
12	Soil moisture equipments		
13	Radiation instruments (Global & net radiation)		
		B. Optional instruments	
1	Lysimeter	Sunshine recorder	Wind vane
2	Potentiometer	Dew gauge	Anemometer
3	Micro voltmeter	Self recording rain gauge	Dew gauge
4	Thermopile sensing element for short & long wave radiation	Thermo-hygrograph	
5	Contact recording anemometer		
6	Automatic weather station		

Specific purpose observatory

This observatory is set up temporarily or permanently for the observation of one or several elements and/or of specific purpose for which the observations are required.
Eg. Observation using pilot balloons and radiosonde

General precautions for installation of meteorological instruments

(i) All the tall instruments should be kept on North side of the observatory so that their shadow may not fall on the other instruments.

(ii) The face of the Stevenson's screen should always open in the North in Northern Hemisphere so that the direct solar radiation may not fall on the instruments while recording the observations and vice-versa in southern Hemisphere.

(iii) If a small laboratory building is required, then it should be very small in the Northern side of observatory so that its shadow may not fall over the observatory area where instruments are installed.

(iv) All the instruments should be installed in accordance with the norms and instructions of India Meteorological Department/World Meteorological Organization (WMO). This will keep the uniformity and comparison of weather data from place to place over the globe.

(v) Soil thermometers should always face South in Northern Hemisphere and vice-versa.

(vi) The instruments should be properly well spaced so that these are easily approachable and may not be influenced by the shadow of the surrounding instruments.

Some important geographical terms

(i) Latitude: Latitudes are imaginary lines drawn parallel to the equator running from west to east. Latitude of a place is the distance either north or south of the equator which is measured as an angle whose apex is at the center of the Earth. One degree of latitude is approximately equal to 111 kilometres. There are 180 latitudes in total and 90 are running in the northern hemisphere and 90 are running in the southern hemisphere. Some of the important latitudes are 0° (Equator), 23½° N (Tropic of Cancer), 23½° S (Tropic of Capricorn), 66½° N (Arctic circle), 66½° S (Antarctic circle), 90° N (North pole) and 90° S (South pole)

(ii) Longitude: Longitudes are imaginary lines drawn across the equator connecting North Pole and South Pole. The distance of a place east or west of the meridian of Greenwich or the Prime Meridian as an angle is known as longitude of a place. A meridian is a line joining places which has their noon at the same time. There are 360 longitudes in total and 180 are eastern longitudes and 180 are western longitudes. Some of the important longitudes are 0° (UTC – Universal Time Co-ordinate), 180° (IDL – International Date Line). Longitudes are important for time calculation.

(iii) Altitude: It is the vertical height above the mean sea level.

(iv) Poles: The two points at the northern and southern extremities of the earth known as the North Pole and South Pole, which forms the ends of the earth's axis.

(v) Hemisphere: One half of the earth's surface formed when a plane through its centre bisects the earth. The earth is usually divided into Northern Hemisphere and Southern Hemisphere.

(vi) Local time: The time at any point on the earth's surface calculated by the position of the sun. This is also called solar time. In view of the rotation of the earth from west to east on it axis, places lying on the same longitude will thus have the same noon and the same local time. As the earth rotates 360° once in 24 hours, local time changes by an hour for every 15 longitude, or 4 minutes for every 1° longitude.

(vii) Standard time: The surface of the earth has been divided into 24 zones according to the hours in a day. These are called time zones and each zone extends over about 15° longitude or approximately 7 $^1/_2$° on each side of the standard meridian. All places within the zone have the same standard time for the particular region. In India, the longitude 82½° E near Allahabad is selected for reckoning the Indian Standard Time (IST). Large countries which stretch from east to west have more than one standard time. For example, Canada has 6 time zones and old Soviet Union had 11 time zones. The Greenwich situated on zero degrees longitude in U.K. and is used as the standard for reference for all over the world.

Table 1.2. Details of meteorological instruments and observation timings at Agromet Observatory, IGKV, Raipur.

S. No.	Weather parameter	Name of Instruments	Accuracy	Observation Frequency	Time of observations
1.	Rainfall	(i) Non-recording rain gauge	± 0.2 mm	Twice daily	0830 hrs IST and 1400 hrs LMT
		(ii) Self-recording rain gauge	± 0.5 mm	Continuous	Chart setting at 0830 hrs IST
2.	Air Temperature	(i) Maximum thermometer	± 0.1° C	Twice daily	0700 & 1400 hrs LMT
		(ii) Minimum thermometer	± 0.1° C	Twice daily	0700 & 1400 hrs LMT
		(iii) Grass minimum thermometer	± 0.1° C	Once daily	Just before sunrise
		(iv) Bimetallic thermograph	± 0.25° C	Continuous	Chart setting at 0830 hrs IST
3.	Evaporation	(i) U.S. open Pan Evaporimeter	± 0.1 mm	Twice daily	0830 hrs IST & 1400 hrs LMT
4.	Relative humidity	(i) Dry and wet bulb thermometer	± 0.1° C	Twice daily	0700 & 1400 hrs LMT
		(ii) Hair hygrograph	± 2%	Continuous	Chart setting at 0830 hrs IST
5.	Wind speed	(i) Cup Anemometer	± 0.1 km	Twice daily	0700 & 1400 hrs LMT
6.	Wind direction	(i) Wind vane	± 10 degree	Twice daily	0700 & 1400 hrs LMT
7.	Sunshine duration	(i) Campbell strokes sunshine recorder	1 min./hr	Continuous	Card fitting either before sunshine or after sunset
8.	Soil temperature	(i) Soil thermometers at various depths.	± 0.1° C	Twice daily	0700 & 1400 hrs LMT
9	Dew	(i) Dew gauge plates	± 0.1 mm	Once daily during winter season	Before sunrise

Exercise:

1. What is purpose of an agromet observatory?
2. Draw the layout of the agromet observatory and list out the instruments installed.
3. Write site selection criteria for establishment of agromet observatory.
4. What is the type of observatory installed at your college?
5. Mention the most and least variable weather element?
6. **Latitude:**
   - i) What it means?
   - ii) What is the latitudinal position of Chhattisgarh and India?
   - iii) What is the latitude of your college observatory?
   - iv) What is the use of knowing latitude?
7. **Longitude :**
   - i) What it means?
   - ii) What is the longitudinal position of Chhattisgarh and India?
   - iii) What is the longitude of your college observatory?
   - iv) What is the use of knowing longitude?
8. **Altitude:**
   - i) What is altitude and how do you measure it?
   - ii) Altitude of our observatory ---------------
   - iii) Name the place of highest altitude in Chhattisgarh and India.

Practical No. 2

Title: **Calculation of time**

Objective: **To acquaint the students about coordinates of the agromet observatory and calculation of IST and LMT**

A series of crossing lines on a map or a globe, which enable to identify the location of any point on the Earth, is known as the Earth Grid. Time calculation is done based on the longitudinal position of the place with reference to Greenwich meridian (UTC).

Coordinates of the observatory

For locating the observatory in the map and other purposes like time of observation of air temperature and humidity for getting correct atmospheric pressure the position of observatory or station must be accurately known. The coordinates of an observatory or station are

i) Latitude
ii) Longitude
iii) Altitude

Indian Standard Time (IST)

The surface of the Earth is divided into 24 'time zones' the way in which there are 24 hours in a day. The time established in each of the zone is called as 'Standard time'. The Indian Standard Time (IST) is the Local Mean Time (LMT) for the meridian of longitude 82°30' E. This is the longitude of Allahabad, which is taken as standard longitude for our country. Since each degree is equal to four minutes of time, the IST is 5½ hours ahead of Greenwich Mean Time (GMT). The GMT is also known as Universal Time Co-ordinate (UTC).

Local Mean Time (LMT)

This is the local time based on the transit of the mean Sun. To calculate LMT from IST, it is essential to know the longitude of the station.

The relation between LAT, LMT and IST

$$LMT = IST \pm 4(L_1 - L_2)$$

Where L_1= Standard Meridian (82°30' for our country) L_2 = The meridian of the station

Positive sign is used when particular place is located at western side of Allahabad

Negative sign is used when particular place is located at eastern side of Allahabad
If station is to the west of standard meridian subtract 4 minutes for every degree from the IST.

Sample Calculation:

Station	: Raipur
Date	: Select a date which you plan
Longitude	: 81°36' E i.e. 81.60°E
Standard meridian	: 82° 30' i.e. 82.5°
LMT	= IST + 4 (82.5- 81.6)
	= IST + 4 (0.9)
	= IST + 3.6 (or) 4 minutes

If IST is 07 h 00 m, then

LMT = 07 h 00 m + 4 m = 07 h 04 m

The above calculations can be used in the meteorological observatories in which the observations are to be recorded. It is to mention that the observations shall be recorded as precise and accurate as possible at the prescribed timings as per the instructions of the India Meteorological Department.

Exercise:

1. What do you understand by the term coordinates?
2. Write full form of the following : IST, LMT, UTC, GMT
3. The difference between IST and GMT is ----------------.
4. Calculate the LMT for the following stations, if IST is 07:00 Hrs.

Station	**Longitude**	**LMT**
Ambikapur	83.20°E	
Jagdalpur	82.03°E	
Mahasamund	82.10°E	
New Delhi	77.20°E	
Kanyakumari	77.55°E	
Mumbai	72.83°E	
Guwahati	91.73°E	
Jaisalmar	70.90°E	

Practical No. 3

Title : **Study of single Stevenson's Screen and measurement of air temperature**

Objective: **To expose the students about single Stevenson screen and training on measurement of air temperature**

Single Stevenson's screen:

To get true air temperature the thermometers should be shaded from direct sunlight and rainfall. But at the same time good ventilation is essential. These conditions are provided by the special shelter called Stevenson's screen. This special wooden box designed by a British scientist Thomas Stevenson in 1864. It admits a free movement of air and the box is painted white to reflect the solar radiation. A double roof with intervening of air space prevents direct heating of the instruments. The upper roof has a mild slope to drain off the rain water (Fig 3.1). The lower height of the box should be fixed at 4 feet or 1.2 m from the ground. It has one door or window which should be opened only in 'Northern' side in northern hemisphere and 'Southern' side in southern hemisphere to avoid the sun rays falling directly on the thermometers.

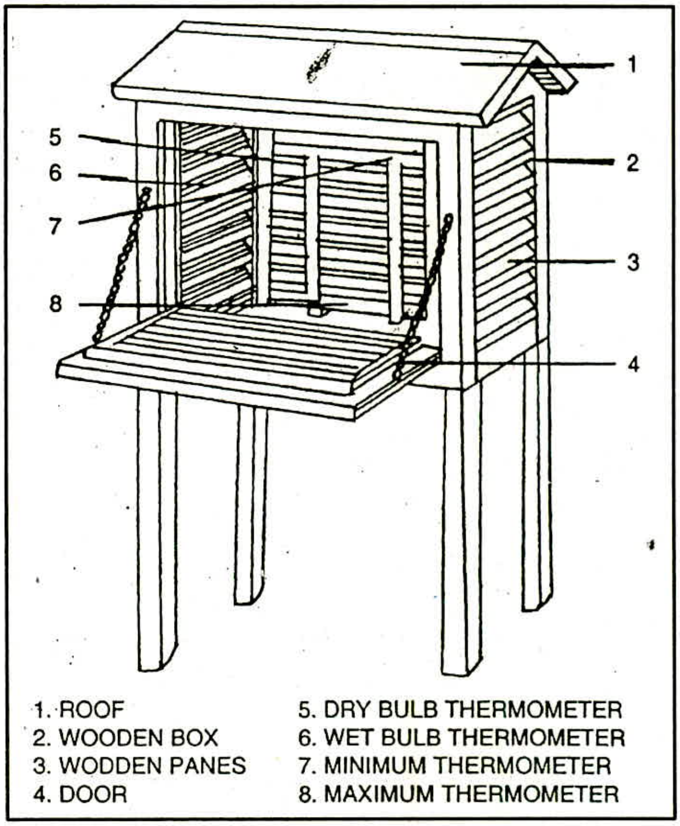


Fig 3.1. Single Stevenson's Screen

There are two types of Stevenson's screen. They are Single and double Stevenson's screen. The single Stevenson screen is meant for keeping the instruments like dry bulb, wet bulb, maximum and minimum thermometers and double Stevenson's screen is used to house self recording instruments namely, thermograph, barograph and hygrograph etc. The dimensions of two Stevenson's Screen are as follows:

Name of the screen	Length (cm)	Width (cm)	Panes Height (cm)
Single Stevenson	45.5	27	38
Double Stevenson	91.0	27	38

Minimum and Maximum thermometers are kept horizontally whereas wet and dry bulb thermometers are kept vertically on either side of minimum and maximum thermometers.

Air temperature:

Temperature is defined as degree of hotness or coolness of a body. Temperature controls the rate of crop development. There are different instruments to measure the air temperature.

Units of measurement:

Name of the unit	Symbol	Reference point		Name of the inventor and year
		Lowest (Melting point)	Highest (Boiling point)	
Fahrenheit	°F	32°	212°	G D Fahrenheit, 1724
Celsius or Centigrade	°C	0°	100°	Anders Celsius, 1742
Kelvin	K	273.15°	373.15°	Lord Kelvin, 1848

(Absolute Zero (0 K or -273.15°C) represents the temperature at which all the molecular motion is ceased.)

Relationship between the units:

i) ° C = 5/9 x (°F-32) or (°F-32) / 1.8
ii) ° F = 32 + (9/5 x °C) or 32 + (1.8 x °C)
iii) K = °C + 273.15
iv) °C = K – 273.15
v) K = 5/9 x (°F-32) + 273.15
vi) °F = 9/5 x (K – 273.15) + 32

Maximum thermometer

Maximum thermometer records the highest temperature recorded in a particular day. It is working based on the principle that expansion of mercury occurs due to change in air temperature which is measured by observing the height of mercury column in the bore (capillary) of the thermometer.

When temperature increases, the mercury expands and is forced through the constriction. When temperature falls, the constriction prevents the return of mercury and keep the top of the mercury column remaining at the highest point. This should be read to the nearest tenth of a degree. After each observation, the maximum thermometer has to be set and kept ready for the next observation. It is set by swinging the thermometer in horizontal position till the thermometer reads the same value as that of the dry bulb temperature (Just like clinical thermometer). In general, setting of maximum thermometer is done during morning hours. Range of maximum thermometer is between -35°C to 55°C (Fig 3.2).

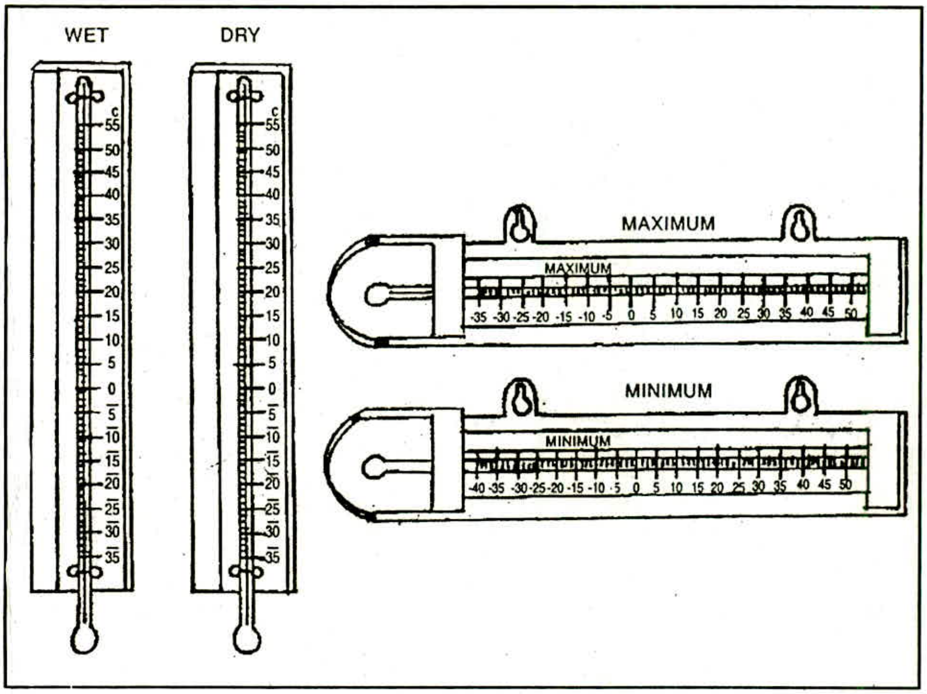


Fig. 3.2. Thermometers in Stevenson's Screen

Minimum thermometer

Minimum temperature is the lowest air temperature recorded during a day. Minimum thermometer is used to record the lowest temperature in a day. This thermometer has a large bore and its fluid is colourless ethyl alcohol or alcohol. The working principle of thermometer is expansion and contraction of alcohol in the bore (capillary) of the thermometer due to changes in air temperature. Within the liquid in the bore of the tube, a tiny dark dumb bell shaped index, made up of a metal is present. This index is placed in the alcohol with its end initially just touching the miniscus at the end of the column. Surface tension prevents the index breaking through the surface.

As the temperature decreases, the contracting alcohol column drags the index along with it. However, if the temperature further increases, the index remains in same position. The farthest / right end of the index from the bulb indicates the minimum temperature recorded since the thermometer was last set. Resetting of minimum thermometer should be done during afternoon hours and it can be accomplished by inverting the stem until the index slides down the stem. This thermometer is graduated from –40°C to +50°C (Fig 3.2). This should also be read to the nearest tenth of a degree, like maximum thermometer.

Dry and wet bulb thermometers

Dry bulb thermometer records the instantaneous air temperature, whereas the wet bulb thermometer records air temperature when its mercury bulb is surrounded with water vapours at saturation level at the environmental air temperature and pressure. These thermometers consist of mercury bulb at one end and connected with the tube which contains a hole in which mercury is filled (Fig 3.2). The bulb of wet bulb thermometer is covered with a piece of muslin cloth which is kept constantly moist by a wick dipping in distilled water. Cooling of the wet bulb thermometer is proportional to the rate of evaporation of water from its wick. The rate of evaporation is in turn dependent upon saturation deficit of the surrounding air. When the air is very dry, rapid evaporation of water from the wick cools the wet bulb thermometer. The difference between dry bulb and wet bulb readings at a given time and place provides indication of humidity of the air and dew point temperature. Normally, a large difference indicates a low relative humidity and vice-versa. When dry and wet bulb thermometers show the same readings, the air attains saturation point and relative humidity is 100 percent. The actual value of relative humidity and dew point temperature is obtained from hygrometric tables corresponding to the readings of dry and wet bulb temperatures. These thermometers are graduated from –35°C to +55°C. This should also be read to the nearest tenth of a degree.

Thermograph

Thermograph is an instrument for getting a continuous and automatic recording of air temperature. The thermograph consists of a temperature sensitive bimetallic element which is connected by a system of linkages to a pen recording on a chart fixed on a drum driven by mechanical clock. The sensitive element of thermograph, most commonly used for routine recording, is either a bimetallic strip or a bourden tube. Two metals having widely different co-efficient of thermal expansion like invar and bronze or steel and brass are welded together and rolled in the form of a thin single strip bimetallic element. One end of arc or helix, is attached to the frame of the instrument, while the other end is fixed to a horizontal spindle to which the pen arm is screwed when the temperature changes, the variations in the expansion of two metals takes place with the increase or decrease of curvature of arc and thus helix either coils or uncoils (Fig 3.3). These variations are transmitted to the pen point where these are recorded on a chart fixed on a revolving clock drum.

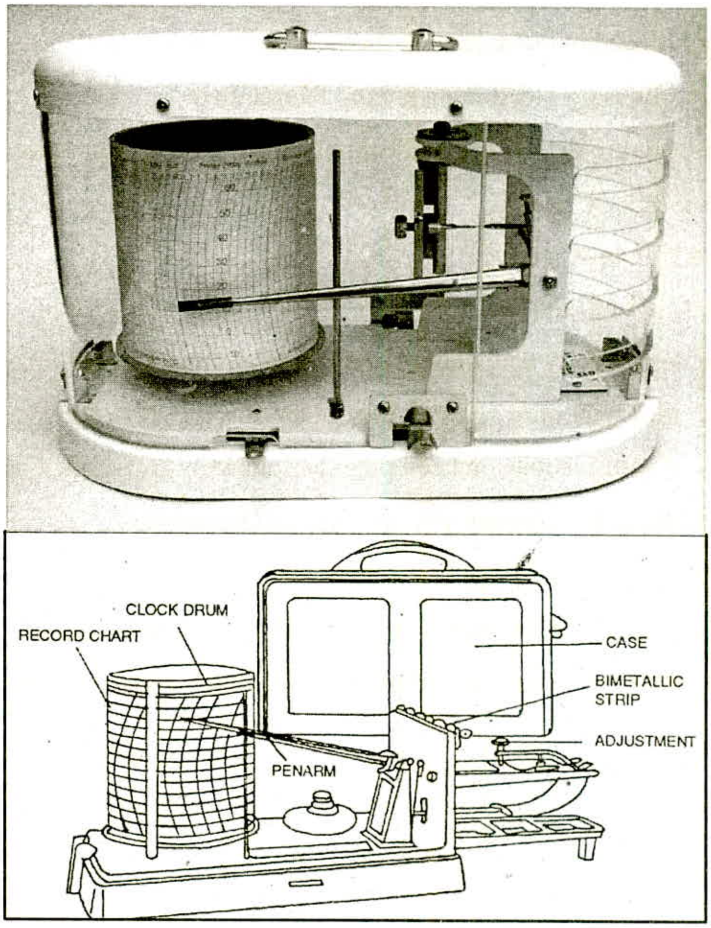


Fig 3.3. Thermograph

Chart number 156 is used and the diameter of the clock drum is 93.3 mm. The chart is having horizontal scale (X – axis) in hours and vertical scale (Y – axis) in °C with a range of 0 to 40°C. The drum completes one round in 24 hours with the curve on the graph for a continuous recording of air temperature for 24 hours.

Important terms :

i) Daily mean = Max. temp + min. temp / 2

ii) Daily range = Difference between maximum and minimum temperatures

iii) Monthly mean = Monthly mean max. temp + Monthly mean min. temp / 2

iv) Monthly range = Difference between the lowest and highest temperature reached

v) Annual mean = Average of 12 months mean

vi) Annual range = Difference between the warmest and coolest monthly mean

Exercise:

1. Describe the Single Stevenson's Screen with figure.
2. Why Stevenson's screen is painted white?
3. In which direction Stevenson's screen should be opened in Northern Hemisphere and why?
4. Why alcohol is used in the minimum thermometer?
5. Why constriction is provided in maximum thermometer?
6. At what temperature the Celsius and Fahrenheit scales will read same value.
7. Convert 35°F in to °C and K.
8. Convert 300 K in to °C and °F.
9. Convert 25°C in to K and °F.
10. Express the human body temperature in the units of Celsius, Fahrenheit and Kelvin.
11. Collect the mean monthly temperature data for the last ten years from Agro-met observatory of your institute and compute the following and show it in the graph chart.
    i) Monthly mean temperature from January to December.
    ii) Monthly temperature range for each month.
    iii) Which month is the hottest and mention the temperature reached.
    iv) Which month is the coldest and mention the temperature reached.

Practical No. 4

Title: Measurement of relative humidity
Objective: To train the students about measurement of relative humidity

Humidity is general term used to describe the amount of water vapour present in the atmospheric air. It is an important agro-climatic factor in crop production as it is a major determinant of potential evapo-transpiration. This is not an independent variable but is closely related to the rainfall and temperature

Methods of expressing the humidity:

Relative humidity: This is the ratio of actual water vapour content of atmosphere to the maximum water vapour capacity of the atmosphere at a given temperature. It is expressed in percentage.

Absolute humidity : Weight of water vapour in a given volume of air. Unit: g / m^3

Specific humidity : Weight of water vapour per unit weight of air. Unit : g / kg

Mixing ratio : Weight of water vapour per unit weight of dry air. Unit : g / kg

Vapour pressure : This is the amount of partial pressure produced by the water vapour in the air and expressed in the units of millibars or mm of mercury.

Dew point temperature: Temperature to which a parcel of air must be cooled in order to reach saturation (100% humidity).

Measurement of humidity:

Relative humidity is most commonly used term to express the water vapour content of air. It is measured by using temperature data from dry and wet bulb thermometer kept in Stevenson's screen. The details of dry and wet bulb thermometers have been discussed in the previous exercise. Hygrometric table is ready reckoner to get relative humidity and dew point temperature.

Hygrograph or Hair hygrograph:

It is an instrument used for continuous recording of relative humidity of the atmosphere. This consists of strands of human hair which changes their length in proportion to the changes in the relative humidity. The hair will be getting longer as the humidity increases and shrink while the humidity decreases. This movement activate the pen moving over the chart which is calibrated between 0 and 100 per cent. The rotating drum with chart complete one revolution in 24 hours and the chart number used in hygrograph is 398. Diameter of the drum is 93.3 mm.

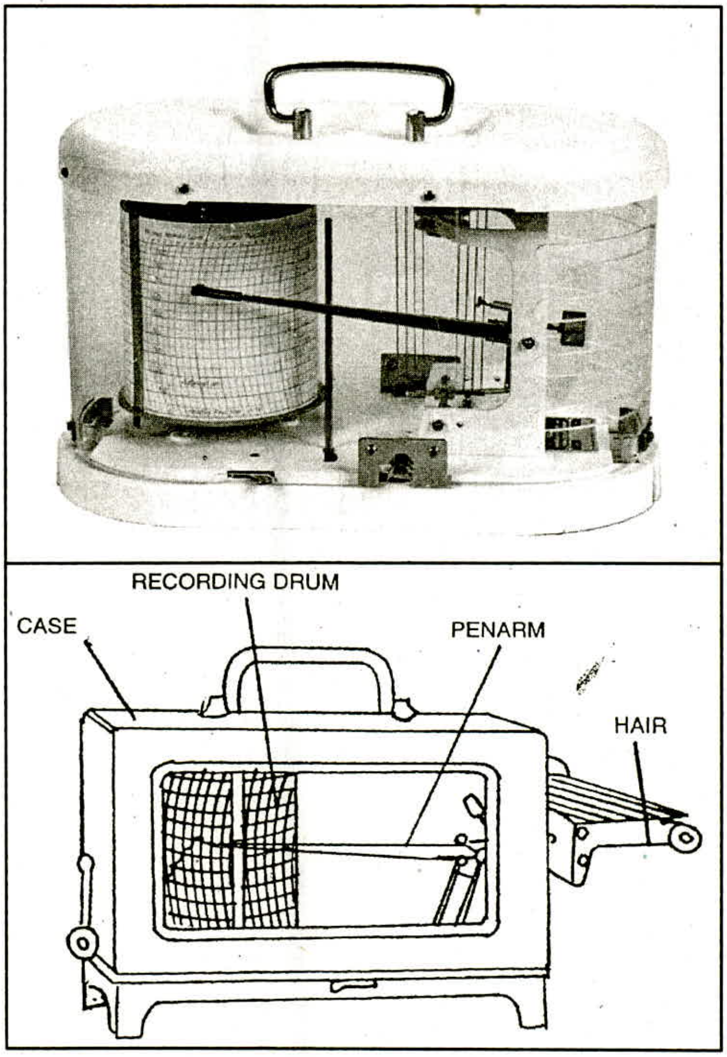


Fig 4.1. Hair hygrometer

Measurement of relative humidity and vapour pressure in the cropped field:

Psychrometer: It consists of two identical thermometers and one of which is tied with a thin muslin cloth. The cloth is wetted with water and continuous current of air is passed over it, which evaporates water and the temperature of the wet bulb thermometer drops according to the rate of evaporation. Thus from the dry and wet bulb temperatures, relative humidity, dew point temperature and vapour pressure can be calculated using psychrometric tables. Psychrometers are useful to find out the microclimatic conditions in the cropped field. There are two types of psychrometers available. They are Assmann psychrometer and Whirling psychrometer (Fig 4.2 a & b).

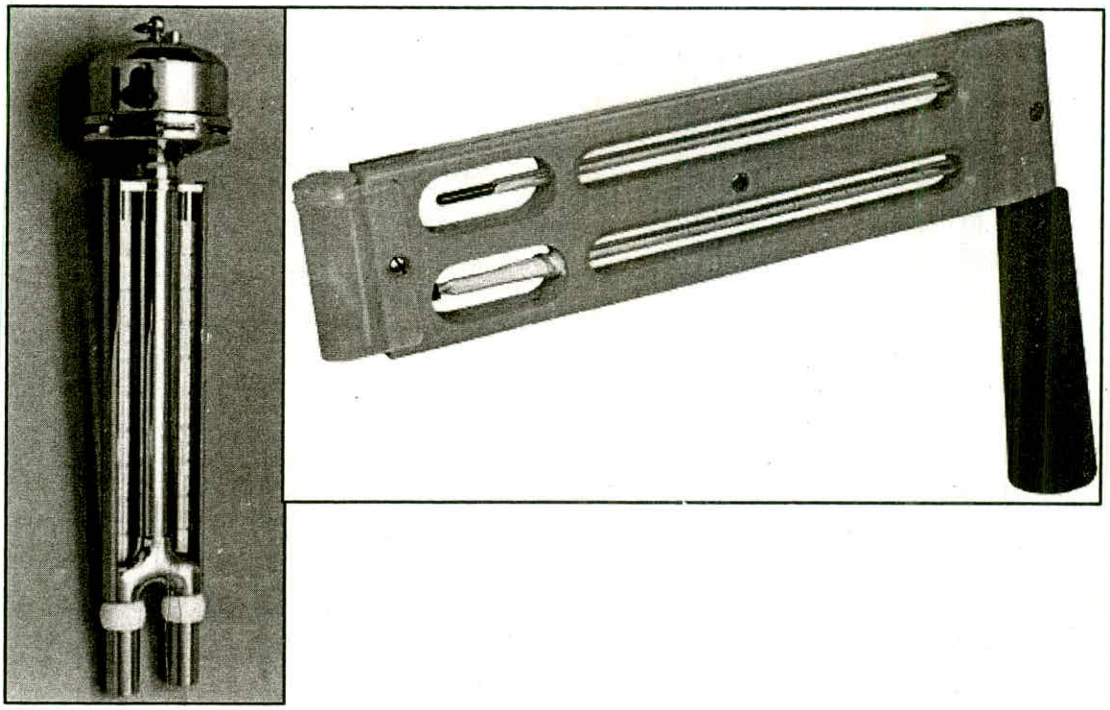


Fig 4.2. (a) Assmann Psychrometer (b) Whirling Psychrometer

Exercise:

1. Write the different terms in which humidity can be expressed with their units.
2. Compute the dew point temperature and relative humidity from the following data.

Dry bulb temperature (°C)	Wet bulb temperature (°C)	Relative humidity (%)	Dew point temperature (°C)
45.8	25.6		
37.5	19.4		
28.7	24.3		

3. Name the instrument which is useful to measure humidity in the cropped field.
4. Collect the mean monthly relative humidity data for the last ten years form Agro-met observatory of your institute and compute the following and show it in the graph chart.

i) Monthly mean relative humidity from January to December.

ii) Mention the month during which lowest relative humidity is observed and write the value.

iii)Mention the month during which highest relative humidity is observed and write the value.

Practical No. 5

Title : Measurement of soil temperature

Objective : To acquaint the students about soil thermometers and their principles Soil temperature

Soil temperature is also an important micro-meteorological parameter like air temperature. This parameter influences the crop growth starting from seed germination, root development to harvesting. Soil temperature also plays an important role in deciding the microbial activity in the soil. Soil temperature affects the uptake and mineralization of nutrients. The presence of organic matter and the soil texture are influenced by soil temperature.

The diurnal range (difference between day and night time values of any parameter) of soil temperature is high at the surface and decreases rapidly with depth, becoming low at the depth of about 30 cm during the summer season. However, in winter, the soil temperature at surface is lower but increases with the soil depth. While the diurnal variation of soil temperature is negligible at depths of 30 cm of more, the seasonal variation becomes negligible at much deeper depths.

Soil thermometers are used for measuring soil temperatures. Indian Meteorological Department has recommended three different depths (5 cm, 10 cm and 20 cm) to measure the soil temperature at agro-met observatories. The thermometers used beyond 30 cm depth are known as earth thermometers and they are used for specific purpose.

Soil thermometers

Soil thermometers are mercury-in-glass thermometers. There is a bend of 120° just above the bulb, rest of the stem being straight. So that when the bulb rests horizontally on the soil at the correct depth, the stem is inclined at 120° from the ground to facilitate during the observation. The temperature can be read with an accuracy of 0.1°C by eye estimation. The thermometer has a range of -5 °C to 65 °C and can be read with an accuracy of 0.1°C.

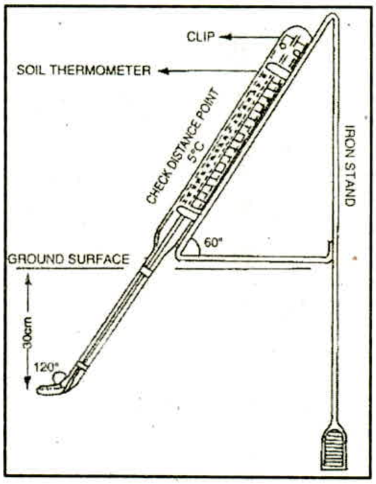


Fig 5.1. Soil thermometer

The soil thermometers are mounted on triangular stands fixed in to the ground as shown in Fig 5.1. The slopping side of the stand is inclined at 60° to the ground surface so as to support for the correct inclination of thermometers. Soil thermometers are installed inside the observatory enclosure to southern end. It is desirable to install the thermometers of three depths at 45 cm distance with graduated marking facing south direction.

The observation of soil thermometers are taken daily at 0700 hrs and 1400 hrs LMT in order of 5, 10 and 20 cm. While taking reading the observer should sit in front of the thermometers, sufficiently away so as not to cast shadow on the ground near thermometers. The plot should be free from any vegetation by removing weed grasses.

Exercise:

1. Why soil thermometers face south in Northern Hemisphere?
2. What is diurnal variation?
3. What are the three recommended soil depths to measure the soil temperatures?
4. Name the liquid which is used in soil thermometers.
5. How soil temperatures are measured at the soil depths more than 30 cm?
6. Collect the soil temperature data for different depths measured in morning and afternoon hours during summer month (May) and winter month (December) from your agro-met observatory and understand the seasonal variation.

Practical No. 6

Title: **Measurement of rainfall**

Objective: **To study working principle and measurement of rainfall through ordinary and self recording rain gauge**

Rainfall is the most important weather parameter for agriculture in general and rainfed /dry land agriculture in particular. It is said to be that Indian agriculture is gamble of monsoon rainfall. Success or failure of rainfall during monsoon period decides the Indian economy. Rainfall is vital component of hydrological cycle.

Rainfall is measured in term of depth of water (millimeter) on a solid surface provided that rain water is neither allowed to percolate nor runoff / evaporation or loss in any form. The device used to measure rainfall is known as rain gauge.

There are three types of rain gauges.

i) Ordinary or Non-recording or Symon's rain gauge
ii) Self-recording rain gauge
iii) Tipping bucket rain gauge

Ordinary or Symon's rain gauge

This instrument is designed to measure the rainfall quantity. It is simple and easy instrument to operate. It is made up of galvonised iron sheet of 12 gauge thickness or fibre glass and plastic. This consists of four parts a) Base b) Body c) Receiver d) Funnel. Rain water entering the gauge from the top of the rim of the funnel is collected in the receiver (Fig 6.1). The rain water thus collected is measured with the help of a measuring cylinder. Depending on the location, funnel with either 112.9 mm diameter (equivalent to 100 cm^2) or 159.6 mm (equivalent to 200 cm^2) are used.

The amount of rain water is measured with the help of a calibrated glass measuring jar, corrected up to 0.1 mm. The rain gauge should be kept on a hard compact levelled platform partially buried in the ground in such a way that the top of the rim should be at a height of 1 foot (30 cm) above the ground surface. The rim should be positioned on a perfectly horizontal plane. This can be done by using a sprit level. In order to avoid the loss of rain drops due to obstruction, the minimum distance of any object should be twice the height of the object.

Rain gauges should be cleaned at regular interval. It should be checked for leaks and dust particles. Leaves should be removed from the collector. The measuring cylinder should be kept clean and a spare measuring cylinder should be available in the observatory.

Self recording rain gauge:

This is designed to give a continuous recording of the rainfall. This instrument not only records the total amount of rainfall but also useful to measure time of start and end of rainfall event and intensity of rainfall.

The main parts of the instrument are i) Float chamber ii) Funnel iii) Strip of bottom of float iv) Entrance tube v) Float vi) Float rod vii) Clock drum viii) Syphon chamber and tube. Chart number 395 is used having 10 mm capacity of rainfall scale on vertical side. The diameter of funnel is 203 mm. This is also made up of galvonised iron sheet of 12 gauge thickness. Now-a-days fibre glass reinforced polyester material is extensively used. The rim of the funnel should be horizontal to the ground and exactly at a height of 75 cm above the ground.

The rain water received by funnel is poured into a chamber through a connecting tube. The chamber has a float and it is connected to a pen arm, through a lever mechanism. The tip of the pen arm is self-inked and touches a calibrated chart which is wrapped around a rotating drum (Fig. 6.2). The drum works with a clock mechanism and completes one rotation in 24 hours. The Y-axis of the chart represents rainfall with a precision of 0.1 mm and X-axis represents time. This instrument has a syphoning mechanism and when the water reaches the maximum level (10 mm) it gets emptied automatically. The pen arm comes down to zero and rises again if there is further rainfall. In case of no rain the pen traces a horizontal line at the zero level. The chart has to be changed every day at 0830 and there should be sufficient ink in the pen. The instrument should always be kept clean and no leaves should enter the funnel. The intensity or rate of rainfall is obtained by dividing the total amount of rainfall with the total hours of the rainfall during a day.

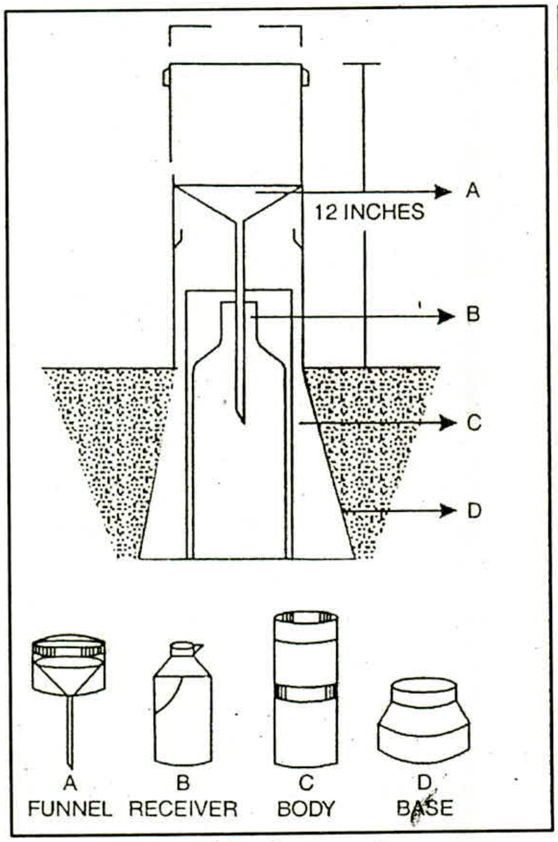


Fig 6.1. Ordinary rain gauge

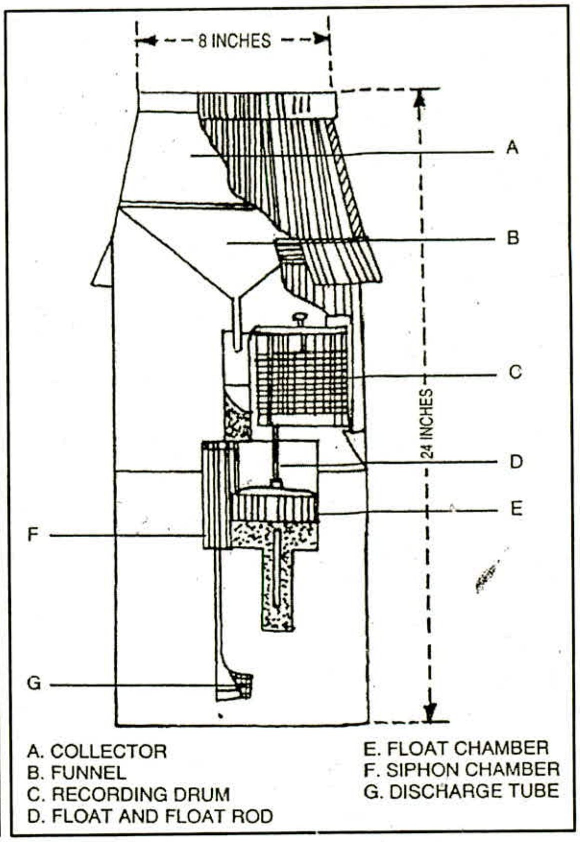


Fig 6.2. Self recording rain gauge

Important facts about rainfall measurements

It is assumed that amount of rainfall collected in the gauge is a representative of the area surrounding the location where measurement is made. Rainfall is measured in terms of depth of water. For example, 100 mm rainfall means that if the rain water is allowed to stand on a levelled surface which neither absorb nor a llows to runoff and evaporation losses, then it would represent a water level of 100 mm in depth. If the volume of rain water or amount of rain water in litres/kilo litres received in a cropped field is to be determined, then area of the field should be multiplied by the amount of rainfall.

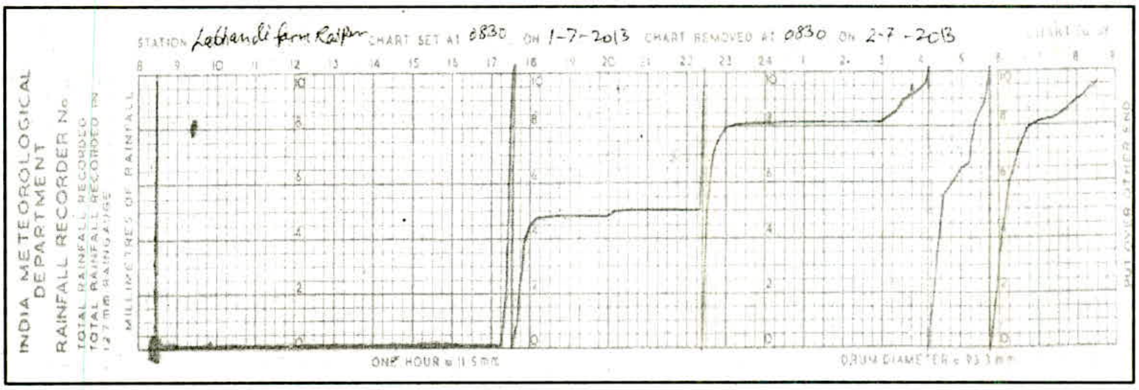
Calculation:

Area of the field: 0.75 acres
Rainfall amount: 25 mm
Volume = Area x Depth
Area = 0.75 acres = 3000 m^2
Depth i.e. rainfall = 25 mm = 2.5 cm = 0.025 m
Volume (or) amount of rainfall water received = 3000 m^2 x 0.025 m = 75 m^3
1 m^3 = 1000 litres
Therefore 75 m^3 = 75 x 1000 = 75,000 litres (or) 75 kilo litres.
Exercise:

1. Write the parts of the ordinary rain gauge.
2. What is advantage of self recording rain gauge?
3. At what time rainfall is measured at the observatory?
4. What is the quantity of water received in kilo litres by a cropped field of 0.25 hectare, if rainfall amount is 48 mm?
5. Calculate the intensity of rainfall for the following rainfall spell.

Date	Time of start and end of rainfall	Rainfall amount (mm)	Intensity (mm/hour)
28.07.2012	1415 hrs and 1630 hrs of IST	190	

6. If there is a building of 25 meters height and a rain gauge is to be installed in its vicinity then how much distance you will keep between the building and rain gauge to avoid the loss of rain drops.
7. Compute time of occurrence, duration and intensity of rainfall from the given chart.



Practical No. 7

Title : **Measurement of bright sunshine hours**

Objective: **To explain the students about working principle and measurement of bright sunshine hours**

The sun is the source of heat energy to the atmosphere as well as earth. The sun generates tremendous amount of heat (about 5 x 10^{27} cal/min) but earth receives very meagre amount of the total energy. The sun rays takes averagely 8.3 minutes to reach the earth and it varies from 8.14 to 8.42 minutes depending up on distance between earth and sun. The sun rays give light from dawn to dusk to the entire earth. Here comes the term “visible” and “bright” sunshine. "Bright" sunshine hours represent the total hours when the sunlight is stronger than a specified threshold, as opposed to just "visible" hours. "Visible" sunshine, for example, occurs around sunrise and sunset, but is not strong enough to excite the sensor. In 2003, the sunshine duration get finally defined as the period during which direct solar radiation exceeds a threshold value of 120 W/m². The bright sunshine hours are measured with the help of Campbell Stokes sunshine recorder. It was invented by John Francis Campbell in 1853 and modified in 1879 by Sir George Gabriel Stokes. In other way it is also indicates cloudless hours of a particular place.

Campbell – Stokes Sunshine recorder:

It consists of a glass sphere of about 10 cm in diameter and a bowl is supported by a semi-circular brass bar (Fig 7.1). The instrument is mounted on a marble base of 20 cm^2. The bowl is made up of gun metal and has a central line engraved transversely across its inner surface to facilitate its adjustment. The inner surface of bowl has three sets of grooves for three types of cards. They are:

a) **Long curved cards or summer cards:** Used from 13th April to 31st August. These cards are introduced through the bottom slot in the concave plate.

b) **Short curved cards or winter cards:** Used from 13th October to the end of February. These are introduced at the top slot.

c) **Straight cards:** When day and night lengths are equal, these cards are used i.e., from 1st March to 12th April and 1st September to 12th October. These are introduced through the middle slot.

Sunshine recorder burns the card by the heat of sun’s rays focussed on the card with the help of glass sphere. The glass sphere acts as a convex lens. The bright sun rays leave a charred or burnt line on the sunshine cards. The cards are graduated in hours for accurate measurement of bright sunshine. The cards are made from good quality paste board, 0.4 mm thick, coloured with matt finish blue ink for easy distinguishable of burns on the cards.

Sunshine recorder is to be installed at a height of 10 feet or 3 meters in the northern side of the observatory. Care should be taken that there should be any obstacles to intervene sun's rays at any time of the day and any part of the year. For precise measurement of sunshine duration, special plastic sunshine hour scale can be used. It is graduated for one hour duration which is divided in to ten equal parts. There are two graduation marks available in the scale. One is to measure straight card and another one to measure long/short curved cards. The tabulation work of hourly values of bright sunshine hours should be entered in the prescribed tabular format and total duration of sunshine should be written on the back side of the card. The glass sphere should be monitored daily and it should be cleaned immediately if any deposit of dust, leaves, dew and bird droppings.

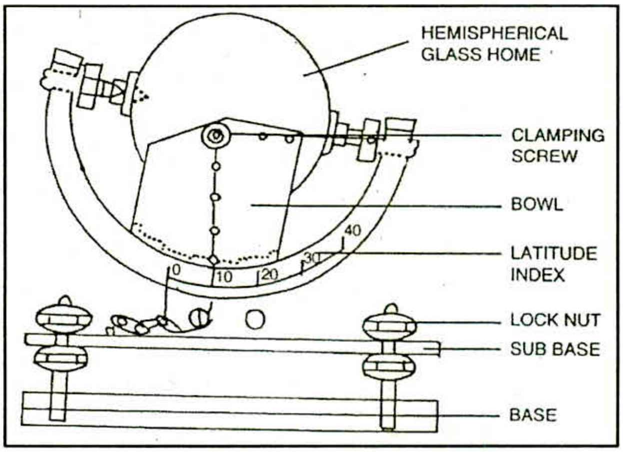


Fig 7.1. Campbell Stokes Sunshine recorder

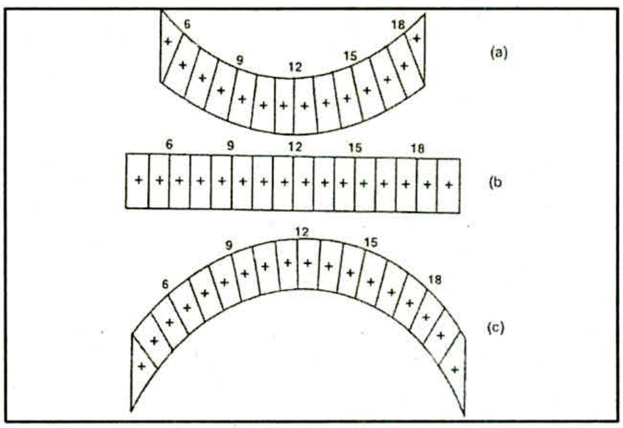


Fig 7.2. Cards of different types used in different season in sunshine recorder (a)Short curved (b) Straight (c) Long curved

Cloudiness:

Cloud cover (also known as **cloudiness** or **cloud amount**) refers to the fraction of the sky obscured by clouds when observed from a particular location. Cloudiness is measured with the help of visual observations at observatory during morning and afternoon hours. It is measured in terms of oktas. The sky is approximately divided in to eight equal parts and in how many parts clouds are present is to be counted and finally summed up for total cloud cover. The range of okta varies from 0 to 8. The total amount of cloud is recorded as 0 when sky is free from clouds and for overcast sky it is 8. The following symbols are used for reporting cloud amount in weather maps (Fig 7.3).

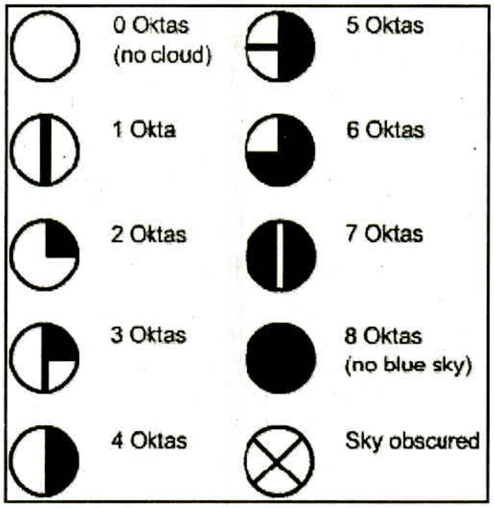


Fig 7.3. Symbols for cloud amount used in weather maps

Exercise:

1. What is threshold value of solar radiation during the period bright sunshine hours?
2. Write the name of the inventors of sunshine recorder and mention the year too.
3. What is the average time taken by sun rays to reach earth?
4. Name the different types the cards used in sunshine recorder along with their period during which they are used.
5. Compute the total sunshine duration by using given card and write the sunshine hours in the prescribed tabular format.
6. Collect the mean monthly bright sunshine hours data for the last ten years from Agro-met observatory of your institute and compute the following and show it in the graph chart.
   - **i)** Monthly mean bright sunshine hours from January to December.
   - **ii)** Mention the month during which lowest bright sunshine hours is observed and write the value.
   - **iii)** Mention the month during which highest bright sunshine hours is observed and write the value.
7. What do you mean by cloud cover and how it is measured? Write the unit for the cloud amount.

Practical No. 8

Title: **Measurement of solar radiation**

Objective: **To expose the students about pyranometer and measurement of solar radiation**

The radiant energy from the sun is transmitted in the form of waves of different lengths called spectrum and the total range of the spectra for all such emissions is called as "electromagnetic spectrum". Almost 99% of the solar radiation is emitted in the wave length of 0.15 – 4.0 μ (Short wave radiation). Of this 9% is in the ultra-violet region and 41% is in visible region and remaining 50% in infra red region. Incoming solar radiation (Insolation) is divided in to two types. i) Direct radiation (Solar radiation received at earth surface without any disturbance/depletion). ii) Diffuse radiation (portion of radiation that reaches the earth surface after having been scattered from direct beam by aerosols or pollutants in the atmosphere). The following table contains name of the radiation measuring instruments and the type of radiation which they could measure.

S.No.	Name of the instrument	Radiation measured
1.	Pyaranometer or Solarimeter	Direct and diffused solar radiation
2.	Pyrheliometer	Direct solar radiation
3.	Pyrradiometer	Short and long-wave radiation
4.	Pyrgeometer	Long-wave or Infrared radiation (IR)
5.	Net radiometer	Net radiation flux
6.	Spectral radiometer	PAR and near Infra-red radiation (NIR)
7.	Quantum sensor and Line Quantum sensor	PAR or PPFD (Photosynthetic Photon Flux Density - $\mu mol/sec/m^2$)
8.	UV. Biometer	Ultra Violet – B radiation
9.	Albedometer or Inverted Pyranometer	Albedo or reflected solar radiation
10.	Lux meter	Light illuminance

Units of expressing the heat energy:

1.	Joule (J)	:	10^7 ergs
2.	1 cal or gram calorie	:	4.185×10^7 ergs
3.	1 Watt	:	14.3363 cal min^{-1}
4.	1 cal m^{-1}	:	0.06978 watt
5.	1 W	:	1 J/s
6.	1 MJ / m^2/ day	:	11.54 W / m^2
7.	1 cal / cm^2/ min	:	2.91×10^{-9} MJ / cm^2/ min
8.	1 Horse power	:	746 watts

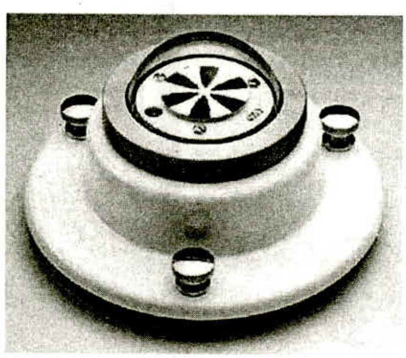
Pyranometer:

A pyranometer is used to measure global solar radiation falling on a horizontal surface. Its sensor has a horizontal radiation-sensing surface that absorbs solar radiation energy from the whole sky and transforms this energy into heat. Global solar radiation can be ascertained by measuring this heat energy. Most pyranometers in general use are now the thermopile type, although bimetallic pyranometers are occasionally found.

Thermoelectric pyranometers are shown in Fig 8.1. The sensing element in this element is a thermocouple with hot and cold areas (Black and white). The greater the radiation intensity, the greater is the temperature difference between white and black areas. Temperature difference is sensed by a differential thermopile whose output is nearly linear to solar radiation. In the case of a pyranometer, methods of ascertaining the temperature difference are as follows:

i) Several pairs of thermocouples are connected in series to make a thermopile that detects the temperature difference between the black and white radiation-sensing surfaces.
ii) The temperature difference between two black radiation-sensing surfaces with differing areas is detected by a thermopile.
iii) The temperature difference between a radiation-sensing surface painted solid black and a metallic block with high heat capacity is detected by a thermopile.

Thermoelectric pyranometers are sealed in a glass dome to protect the sensor portion from wind and rain and prevent the sensor surface temperature from being disturbed by wind. A desiccant is placed in the dome to prevent condensation from forming on the inner surface. The glass allows the passage of solar radiation in wavelengths from about 0.3 to 3.0μ – a range that covers most of the sun's radiation energy. Some models are equipped with a fan to prevent dust or frost, which greatly affect the amount of light received, from collecting on the dome's outer surface. It is necessary to check and clean the glass surface at regular intervals to ensure that the dome wall constantly allows the passage of solar radiation.



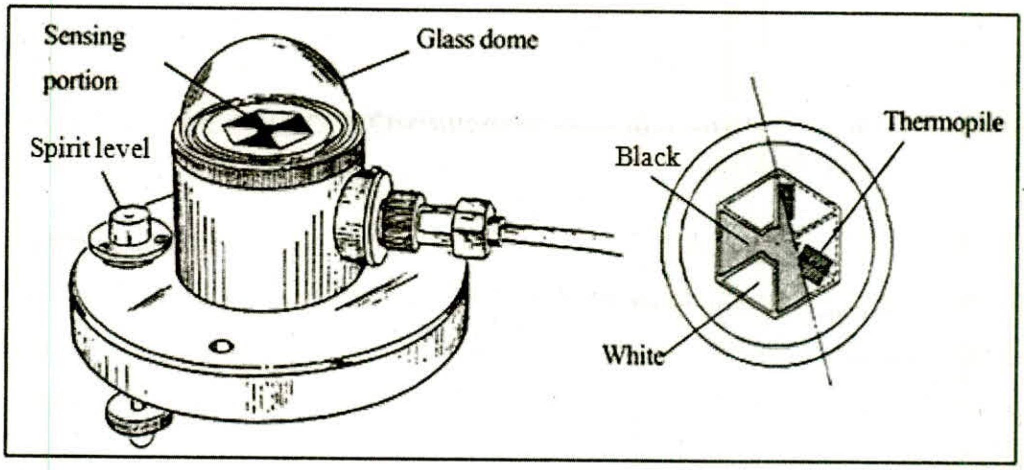


Fig.8.1. Pyranometer

Exercise:

1. What do you mean by electro magnetic spectrum and write the types of incoming solar radiation.
2. Which part of the solar spectrum is utilised by the crop plants for their food-making process?
3. What is the difference between "light from the sun" and "radiation from the sun"?
4. What is the type of the wave length for the radiation from the sun and earth?
5. Write full form of PAR, NIR and IR and the instrument name to measure the same.
6. Write name of the sensing element in pyranometer.

Practical No. 9

Title: **Measurement of evaporation**

Objective: **To understand the working principle of open pan evaporimeter and measurement of evaporation**

A change in the physical state of water from liquid to vapour is known as evaporation. Evaporation from surface is influenced not only by environmental factors but also by the depth, size, state of evaporating surface and surrounding etc. The pan evaporimeter (USWB Class 'A' open pan evaporimeter) is most widely used instrument for evaporation measurement from free water surface. The rate of evaporation from an open water surface can be expressed as the volume of water evaporated per unit area in unit time. For a given area, this is proportional to the depth of water lost in unit time from the whole area. Evaporation is usually expressed in units of depth of water lost in mm per day.

USWB (United States Weather Bureau) Class 'A' open pan evaporimeter

The water lost through evaporation in a given interval of time is measured by adding the known quantity of water to the pan from a graduated cylinder till the water level touches the reference point. The rate of evaporation is calculated by amount of water added to the pan (which is equal to water lost by evaporation) divided by the time interval.

The diameter of the pan evaporimeter is 122 cm in and 25.5 cm in deep. It is painted white and is covered with a lid of hexagonal mesh to protect the water from birds and squirrels. This is made up of galvanized iron/or copper sheet of 20 gauge thickness. 10 mm thick copper is the latest recommended standard. Water level in this application should be maintained up to 20 centimeters. In order to provide undisturbed water surface, a still-well is used. It is kept in the pan at the based and is provided with 3 small openings (120 degrees apart) at its bottom so that the water level of the pan corresponds to that of still-well. The reference point is provided by the brass rod, fixed at the centre of the still-well and is tampered to end at a point exactly 190 mm above the base of the pan.

The pan rests on a wooden platform which is painted white and placed about 3 to 4 inches above the ground surface (Fig 9.1). This allows free circulation of air and also to detect leakages, if any. In addition, it keeps the pan safe during rainy season and there would be no effect of soil surface temperature. A thermometer to measure the temperature of the water is fixed with a clamp to the side of the pan so that the bulb dips 5 cm below the water surface.

Measured quantities of water is added or removed to bring the back the level of water to its original position. Observations with evaporimeter should be taken twice a day at 0830 and 1430 hours IST and the readings are cumulated and expressed as evaporation mm/day.

The observations are to taken as detailed below.

a) Read the thermometer just immersed in the water.

b) When water level is below the reference point, add water to the evaporimeter using the measuring cylinder.

c) Add water until the tip of the fixed point equals the surface of the water in the still-well.

d) For example, one full cylinder and 10 cm .i.e., 30 cm or 300 mm of the water is added to the pan. This divided by 100 i.e. 3.0 mm is the amount of water lost by evaporation from the pan, if no rainfall occurred since the last observation.

e) On a rainy day, if the amount of water taken out to bring the level equal to point is 38 cm, the difference as per the above calibration in the description is 3.8 mm. If the rainfall is 5.7 mm during the day, then the evaporation is 5.7 – 3.8 =1.9 mm.

f) When there is light rain, and the water level is not above reference point, then procedure to be followed is like this. If 20 cm of water is added to the pan (i.e. 2.0 mm after calibration) and rainfall is 1.2 mm, then the actual evaporation is 2.0 + 1.2 = 3.2 mm.

g) If there is heavy/very heavy rainfall, the rain water would fill the pan and water overflow from the pan. During this situation, evaporation may be noted as "overflow".

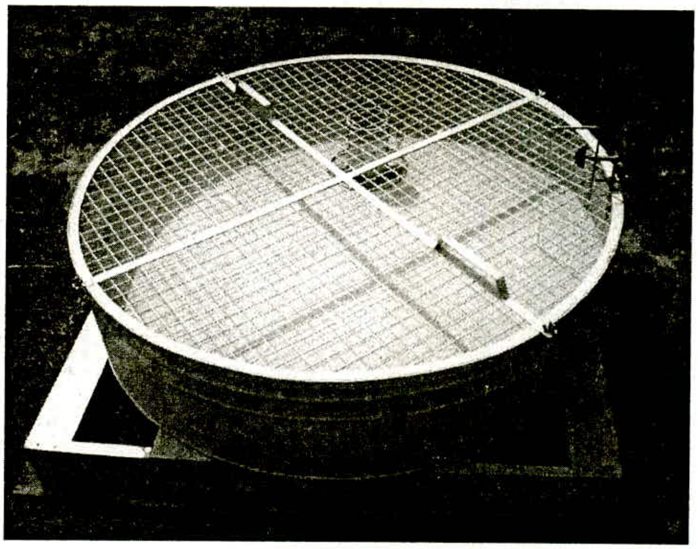


Fig 9.1. USWB Class 'A' Open pan evaporimeter

Evapotranspiration:

It is the combined loss of water due to transpiration from vegetation and evaporation from soil surface. This is measured by means of lysimeters. India Meteorological Department has developed two types of lysimeters. They are i) Gravimetric ii) Volumetric. This will provide direct measurement of evapotranspiration. Though the lysimeters provide direct measurement, it is influenced by a major limitation /assumption in reproduction of physical conditions such as temperature, moisture regime, density of soil etc., with in the lysimeter when compared to main field.

Exercise:

1. What do you mean by evaporation and evapotranspiration?
2. Write the full name of open pan evaporimeter and why it is painted white?
3. What are the reasons to keep the pan evaporimeter on wooden platform?
4. Write the instrument name which measures the evapotranspiration and also its type?
5. Collect the mean monthly evaporation data for the last ten years from Agro-met observatory of your institute and compute the following and show it in the graph chart.
   - i) Monthly mean evaporation from January to December.
   - ii) Mention the month during which lowest evaporation is observed and write the value.
   - iii) Mention the month during which highest evaporation is observed and write the value.
6. Calculate evaporation with the following data.
   - (i) Water added in the pan is 89 cm and there was no rainfall in the past 24 hours
   - (ii) Water removed from pan is 208 cm and rainfall in the past 24 hours was 30 mm.
   - (iii) Water added in the pan is 37 cm and rainfall in the past 24 hours was 3.6 mm.
7. Using the following meterological data recorded for two continuous days, state on which day pan evaporation will be higher?

Weather parameter	**1st day**	**2nd day**
Mean air temperature (°C)	30.0	28.5
Mean vapour pressure (mm of Hg)	15	22
Mean wind speed (kmph)	14	6

8. Compute the rate of evaporation using the following data.

Date	**Time interval**	**Evaporation amount (mm)**	**Rate of evaporation (mm/hr)**
5.1.2012	0900 hrs to 1300 hrs	2.5	
22.5.2012	1100 hrs to 2100 hrs	19.0	
18.8.2012	1300 hrs to 0700 hrs	4.0	

Practical No. 10

Title: **Measurement of atmospheric pressure**
Objective: **To explain the working principle of different types of barometer**

Air has a weight and it exerts pressure on all sides. The pressure exerted by the air column of atmosphere on a unit area on earth surface is known as atmospheric pressure. For meteorological purpose, the atmospheric pressure is generally measured using either mercury barometers or precision aneroid barometers.

Units of atmospheric pressure:

The basic unit pressure in international system (SI) is Newton (N). The unit used to measure the atmospheric pressure for meteorological purpose is hectoPascal (hPa) or millibar (mb) which is equal to 100 N/m^2 or 1000 dynes $/cm^2$. In general, atmospheric pressure is measured based on height, weight and absolute unit of force.

i) **Height based:** At the mean sea level, vertical height of mercury measures 76 cm or 760 mm as against the total atmosphere supported in one square centimetre, extending from the earth surface to top of the atmosphere. It is known as the Standard atmosphere.

ii) **Weight based:** Atmosphere pressure measured in terms of weight by simply multiplying the height of mercury (76 cm) with its density (13.6 g / cm^3).

$$76 \text{ cm} \times 13.6 \text{ g} / \text{cm}^3 = 1033.3 \text{ g} / \text{cm}^2$$

It means that the weight of a unit column of air over one square centimetre surface area extending up to top of the atmosphere weighs just more than one kilogram.

iii) **Force unit based:** Atmospheric pressure can also be measured in force units i.e., dynes / cm^2.

$$P = h\rho g = 76 \text{ cm} \times 13.6 \text{ g} / \text{cm}^3 \times 980.6 \text{ cm} / \text{s}^2$$
$$= 1013250 \text{ dynes} / \text{cm}^2$$

One million dynes / cm^2 = one bar
One bar = 1000 millibar
1013250 dynes / cm^2 = 1.01325 bar = 1013.25 mb
One mb = One hPa

Hence, one standard atmosphere, in terms of absolute force units, is equal to 1013.25 hPa.

Instruments for measuring atmospheric pressure:

1. **Simple barometer:** This simple barometer was invented by Torricelli, an Italian scientist in 1643. In consists of a long glass tube sealed at the upper end and open end dipped in a mercury container whose surface is open to air (Fig 10.1). Pure dry mercury without air bubbles is filled in the tube. By putting thumb on open end, tube is inverted and dipped

into the container having mercury and thumb is taken out with care. A part of the mercury from tube will flow in to mercury dish. Mercury attains a certain height leaving empty space at the top called 'vacuum'. It means there is no atmospheric pressure on mercury column due to vacuum space; however air pressure exists on the container. Any change in the atmospheric pressure on mercury surface in the container is balanced by mercury column in the glass tube. The scale of the glass tube is graduated in centimetres or millimetres to indicate the atmospheric pressure at that temperature.

2. **Aneroid barometer:** It consists of thin, evacuated metal box which alters in shape according to pressure of atmosphere (Fig 10.2). These alterations are signified by a mechanical arrangement of levers and are indicated on a circular scale by means of movable pointer. Any change in the atmospheric pressure will cause the shape alteration of the top of box which either pulled out or pushed in against controlling action of a lever spring. These small changes which are magnified by means of a series of chain which is kept tight by a hair spring.

It is necessary to set and calibrate aneroid barometer with the help of a standard barometer i.e., mercury barometer because, it is not an absolute instrument. This type of barometer is frequently used by weather forecaster because various types of weather conditions like storm, rain, fair and dry weather are marked n the top of the barometer. If barometer indicates low pressure, then the weather is more unpleasant.

3. Mercurial barometers: There are two types of mercurial barometers.

i) Fortin's barometer ii) Kew pattern barometer

i) Fortin's Barometer: It works based on the principle by balancing of column of air against a column of mercury in a sealed glass tube. The height of the mercury column is proportional to the pressure. It consists of a glass tube of uniform cross section and length, which is closed at one end (Fig. 10.3). It is about one metre in length, filled with mercury and then inverted with its lower end open into a movable cistern of mercury. The cistern vessel contains mercury with a flexible leather bag and screw at its bottom. There are two scales on two sides of the tube, one in centimetres and the other in inches. For accurate readings vernier callipers is also attached. The mercury column in the tube is supported by the pressure of the air on the surface of the mercury in the cistern. To take the pressure reading, the height of mercury column is measured on main scale and then vernier scale is read.

a) Read the attached thermometer to the nearest degree before the time specified for barometer observation.
b) Gently tap the cistern and tube of the instrument 2 to 3 times with the fingers.
c) Raise the surface of the mercury in the cistern by screwing up the plunger at the base until the tip of the ivory point just touches its image in the clear mercury surface.
d) Set the lower edge of the vernier tangent to the top of meniscus.
e) Read the scale and the vernier.

f) Check the reading by making a fresh setting.

ii) Kew Pattern Barometer: This is also like Fortin's barometer and also easy to operate. In this cistern vessel is fixed and has no adjusting screw (Fig 10.4). To allow the rise and fall of mercury in the cistern the divisions are made unequal. The initial adjustment of cistern is not required. The steps to set and read this barometer are given below.

- Observe the thermometer attached to the barometer and note the temperature in degree absolute.
- Tap the instrument gently.
- Set the vernier scale properly.
- Note the pressure value.

Corrections to be made for the mercury barometer reading:

- **Temperature correction:** Mercury in the tube also acts for the changes in temperature. When we say 760 mm of mercury we mean that the atmosphere has the pressure equal that of mercury which is at 0°C. Temperature correction is necessary because the density of mercury changes as the temperature changes. For making temperature corrections, a thermometer is fixed in the middle portion of the barometer.
- **Gravitational correction:** The gravitational pull of the earth is not the same every where, because the shape of the earth is not spherical. The equatorial diameter is 43 kms more than the poles. Hence we need to consider the pressure gradient between the pole and the equator. By an agreement all the pressure readings are reduced to 45° latitude as a standard.
- **Instrumental correction:** Most barometers are found to have some diversion due to scale inaccuracy and capillarity. They are grouped under instrumental correction.
- **Altitude correction:** At high altitudes the pressure of atmosphere is very low. The atmospheric pressure decreases by 1 mb by every 10 m increase in height. So all the pressure readings are converted to sea level pressure.

4. **Barograph:** This instrument is used to have a continuous record of the atmospheric pressure. It consists of a battery of six to ten vaccum boxes of aneroid barometers placed one above the other. The reason for large number of vaccum boxes is to reduce the effect of irregularities in any one of them and to make the instrument more sensitive. The motion of these boxes is communicated by a system of levers to an arm which carries the recording pen (Fig 10.5). As the pressure changes, this pen moves up and down over the graph paper which is wrapped around the revolving drum. The drum contains clock work which drives it. It makes one complete revolution in 24 hours. There is rise or fall of pen with change of atmospheric pressure, thus a continuous record of air pressure is recorded on a graph.

5. **Altimeter:** Altimeter works on the principle of Aneroid barometer. Here the principle that the pressure decreases with altitude is used. In Altimeter the dial is calibrated in terms of Altitude. It is used to know the elevation of a particular place.

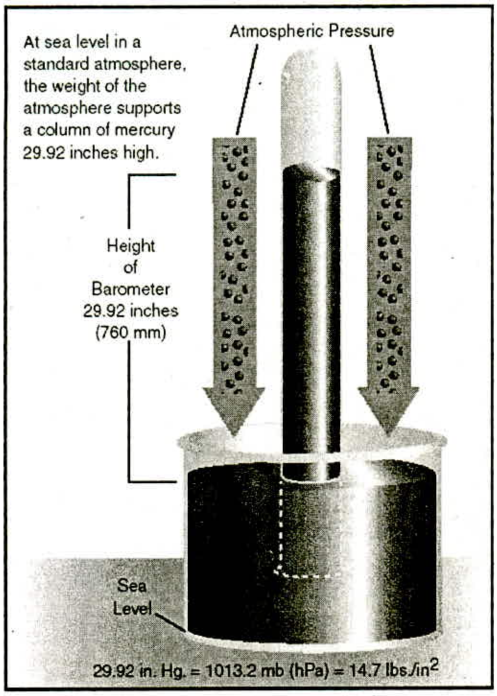


Fig.10.1. Simple barometer

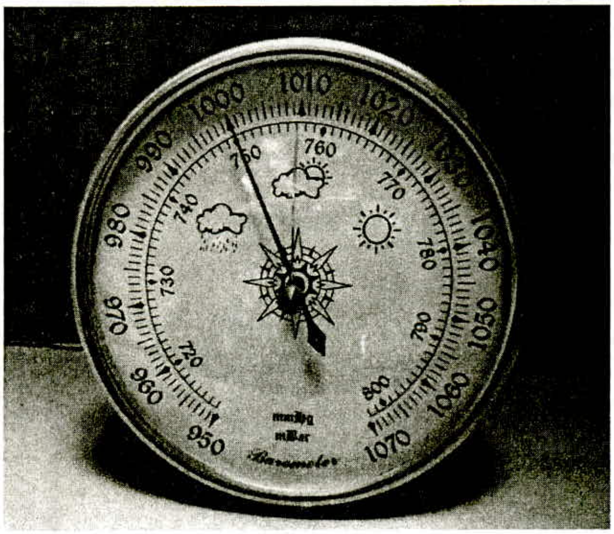


Fig.10.2. Aneroid barometer

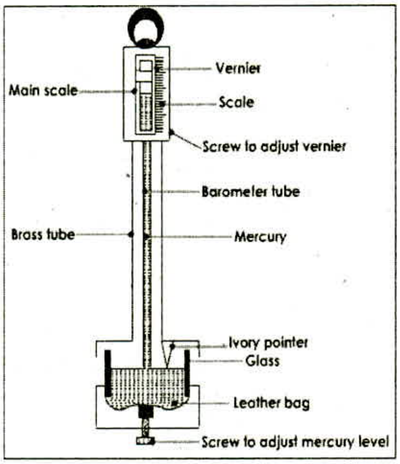


Fig 10.3. Fortin's barometer

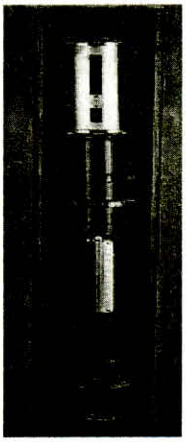


Fig 10.4. Kew Pattern barometer

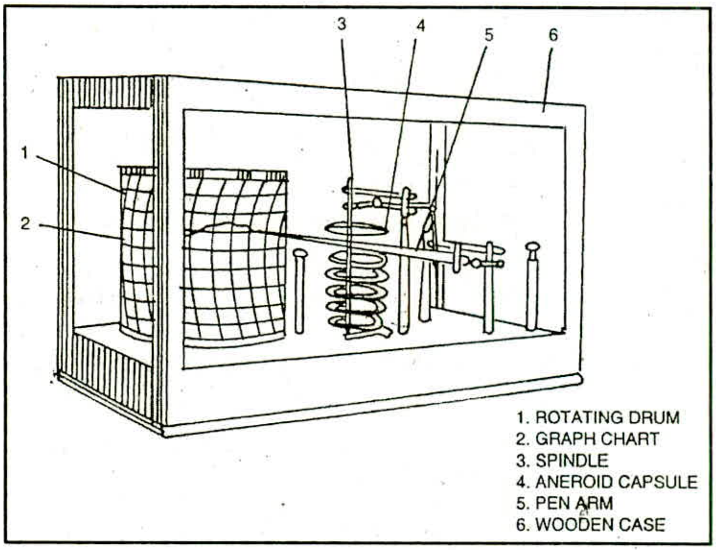


Fig 10.5. Barograph

Exercise:

1) What do you mean by atmospheric pressure?
2) Why mercury is used in liquid barometer?
3) Write different types of units of air pressure.
4) What is the value of one standard atmosphere?
5) How barometer helps in weather forecasting?
6) What is use of altimeter and how does it work?
7) At what rate atmospheric pressure decreases in the atmosphere?

Practical No. 11

Title: **Measurement of wind speed and wind direction**

Objective: **To study on working principle of cup anemometer & wind vane and measurement of wind speed & wind direction**

Horizontal movement of air is called as wind, whereas vertical movement of air is known as 'current'. Wind has to be specified by its speed and direction. Wind speed is measured by cup anemometer and its direction is indicated by wind vane.

Measurement of wind speed

To measure the wind velocity or the wind speed, Robinson cup anemometer is used. In 1846, John Thomas Romney Robinson designed the anemometer with four hemispherical cups. Later, in 1926, John Patterson developed a three cup anemometer, which was improved by Brevoort and Joiner in 1935. The wind pressure on the concave side of the cup is greater than the convex side. This causes the cups to spin around the vertical axis. By means of proper gear reductions, the rotation of the cups is calibrated in terms of wind speed.

This consists of 3 balancing arms which are made up of a very light metal or alloy. Hemispherical or conical cups are attached to the ends of the arms to provide necessary pressure gradient which is caused by the convex and concave surfaces of the cup (Fig 11.1). As the force of the wind on the concave side of the cups is greater than that on the convex side, the cups rotate due to kinetic energy. The balancing arm rotates freely over the vertical axis and at the point of articulation, high grade ball bearing is provided to minimise frictional losses.

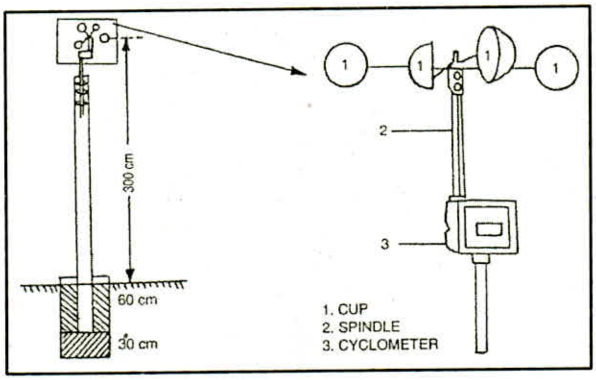


Fig 11.1. Robinson Cup Anemometer

The cups are extended on the vertical axis so that the plane of the cup is in a vertical position. The force of the wind causes rotation. The rotating movement of balancing arms is transmitted to the spindle provided in the vertical axis. The spindle is provided with the grooves which operates gauge and this is transmitted to a fine digital meter. Friction is minimised by lubrication and ball bearings. The gauge is calibrated to real units, tenths, hundreds or thousands. The rate of rotation of the cups increases with the wind speed. The box contains a mechanism which establishes a contact when the cups have rotated a certain number of times. The anemometer is kept on a platform at a height of 10 feet from the ground surface and the range of the meter is 0 to 9999.9.

The wind speed is obtained by measuring the run of the wind in kilometres for a period of 3 minutes at the hour of observation and multiplying it by 20 to obtain the wind speed in kilometres per hour. At agromet observatories the reading of wind speed is taken at 0700 and 1400 hrs LMT.

Wind speed at the hour of observation:

To determine the wind speed at a particular time, two successive readings are taken at an interval of 3 minutes. The difference of the readings is multiplied by 20. For example:

First anemometer readings	=	2090.0
Second anemometer reading	=	2093.1
Wind speed at that particular hour is		
2093.1 – 2090.0	=	3.1 x 20 = 62.0 kmph.

To determine the average wind speed during the past 24 hours, the readings of yesterday and today are required and the yesterday's reading is subtracted from today's reading. The difference is divided by 24, which gives the average wind velocity for the past 24 hours. For example:

Today's anemometer reading at		07 00 hours	=	9563.5
Yesterday's anemometer reading at		07 00 hours	=	9371.6
The difference			=	191.9
Average wind speed	=	191.9 / 24	=	**8 kmph**

Wind direction: The direction from which the wind is blowing is called as wind direction. This is denoted by two methods. They are a) Points of compass and b) Degrees of azimuth, as measured from the true North. The zero point is true north. The other points East, South and West are 90, 180 and 270 degrees respectively. In common practice, the wind directions are referred to compass points such as N, NNW, NW etc.

a) Points of compass: In this system the four main directions are sub-divided into 8 or 16 and it is called 8 or 16 point system.

b) Degrees of azimuth: The zero of the circular scale indicates geographical North, count the degrees while moving in clock-wise direction and it indicates the wind direction.

Instruments to record wind direction:

a) Anemoscope: This records the direction of wind continuously.

b) Aerovane: This measures the velocity and direction of the wind instantaneously.

c) Wind Vane: This is used in observatories to find the wind direction.

Wind Vane:

This consists of balancing arm which is made up of a very light weight metal or alloy which turns freely about a vertical axis (Fig 11.2). Bearings are provided to minimise frictional losses. The bearings should be good enough to give free turn with light winds. In most common type of wind vanes, one end of the balancing arm exposes a broad surface to the wind. This is bifurcated and is known as 'fang'. While the other end is narrow and points to the direction from which the wind blows. This is known as pointer or arrow head.

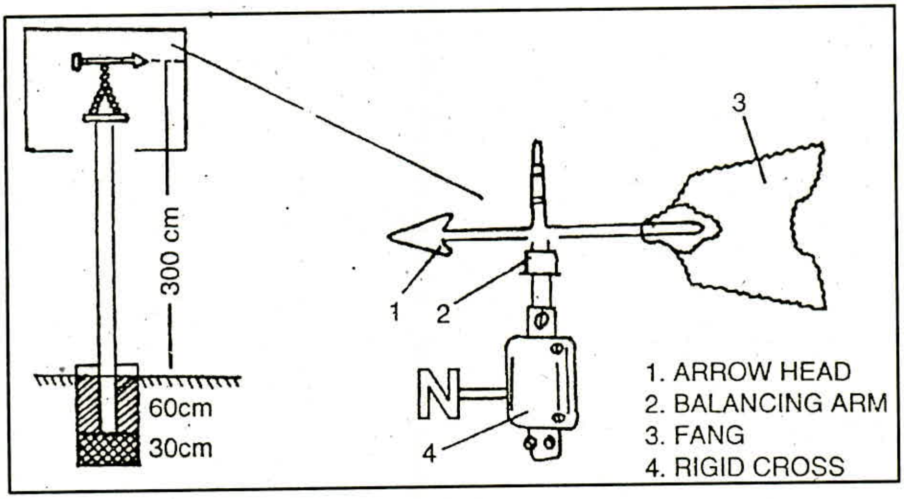


Fig 11.2. Wind vane

Under this movable system four rods are fixed as rigid cross. The arms of this cross are said to be four cardinal directions i.e., North, East, South and West. Some other commercial types are provided with eight to sixteen cardinal direction indicators. The wind vane is installed over a wooden plank which is fixed over the wooden post, at about ten feet from the ground surface. The north indicator should be set to true North and not to the magnetic North.

The observer should stand nearer to the pole and record the mean position of the arrow which oscillates over the cardinal direction. The wind direction should always be recorded as the point from which the wind comes. The wind vane should be watched for few minutes before recording the direction to get the mean observation. The direction of wind is given by the direction of arrow. The absence of appreciable motion of air is termed as 'calm' and cups of anemometer will not rotate in this situation and no attempt should be made to determine the wind direction from the instrument.

Exercise:

1. What do you understand by the words wind and current?
2. Collect the mean monthly wind speed data for the last ten years from agro-met observatory of your institute and compute the following and show it in the graph chart.

i) Monthly mean wind speed from January to December.

ii) Mention the month during which lowest wind speed is observed and write the value.

iii) Mention the month during which highest wind speed is observed and write the value.

3. From the following data of wind speed, calculate the wind speed at the time of observation and for the past 24 hours ending 0704 hours on 2.3.2012.

Date	Time	Anemometer reading	Wind speed (kmph)
1.3.2012	07:04 hrs	7650.0	
1.3.2012	07:07 hrs	7652.3	
1.3.2012	14:04 hrs	7660.5	
1.3.2012	14:07 hrs	7661.5	
2.3.2012	07:04 hrs	7785.6	

4. Name the instruments used to measure the wind direction?
5. What will be normal wind direction during June to September and why?
6. What do you mean by 'windward direction' and 'leeward direction'?
7. What is wind direction, if the arrow head of wind vane is pointing towards the middle of the region between South (N) and South-west?
8. Write the names of the 16 wind directions and also corresponding degrees?

Practical No. 12

Title: **Measurement of dew**

Objective: **To explain the students about measurement of dew using Duv Devani dew gauge**

Due to the cooling of earth surface, the air just above the ground gets cooled and reaches saturation level and the water vapour gets condensed on any surface as dew. Most objects, including grass blades, leaves, and petals, are much better radiators than air and, as a result, are usually colder at night than is the air. The cold surface cools the air in its vicinity, and, if the air contains sufficient atmospheric humidity, it may cool below its dew point. When this happens, water vapour will condense out of the air onto the surface. Dew forms an important secondary source of moisture to vegetations and plays a significant role in plant growth in arid and semi-arid regions. The conditions favourable for the formation of dew are (i) a good radiating surface (ii) a still atmosphere (iii) a clear sky (iv) presence of sufficient water vapour. The beneficial effect of dew on crops is due to its absorption by leaves and reduced transpiration. Dew is measured with the help of Duv Devani dew gauge plates exposed at different heights.

Duv Devani dew gauge

Dew gauge plates are rectangular wooden plates coated with red oxide paint with the dimension of 32 cm x 5 cm x 2.5 cm. The red oxide coating is given to prevent the wood absorbing water. The dew gauge plates should be exposed on a galvanised iron support provided on galvanised iron pipe stand supplied for this purpose. The iron supports are fixed at standard heights of 5, 25, 50 and 100 cm from the ground surface. The dew plates are exposed at sunset time and reading should be taken before sun rise. Each dew plate should be exposed daily at the same level and for this purpose the dew plates may be numbered. In hill stations, dew measurement is taken through out the year where as in plain areas it is measured from 1st September to 30th April even though there is rain.

The dew appearance on wooden plates is compared with the set of photographs (Dew album) which are most nearly represents to its appearance. Dew scale numbers 1 – 8 represent varying amounts of dew as given below.

Dew scale number	**Dew amount in mm**	**Dew scale number**	**Dew amount in mm**
0	No dew	5a, 5b	0.16
1	0.020	6a, 6b	0.21
2a, 2b	0.045	7a, 7b	0.27
3a, 3b	0.075	8	0.35
4a, 4b	0.11	9	No dew but rain

More than one photograph such as a, b are given for same numbers to represent the dew deposits that fall with in the same dew scale number. The dew scale should therefore be represented as 2a, 2b etc., After recording the dew deposited on top surface of dew plate, it should be carefully inverted and the dew deposited on lower surface be examined and dew scale for this surface should be recorded. The proforma of the table in which the dew observations are to be entered is furnished below.

After recording the observations, shake off the dew very thoroughly by swinging the plates vigorously. Never wipe off the deposited dew. Dew plates should be kept under shade after observation. If it is left in open during day time, sunlight and heat would damage the sensitivity of surfaces of dew plates. The surface of dew plates should not be touched with greasy or dirty fingers.

Table 12.1. Proforma of table, to record dew observation

Station: Observation Time:

Date	Dew gauge No. Height ---------cm				Dew gauge No. Height ---------cm				Dew gauge No. Height ---------cm				Dew gauge No. Height ---------cm			
	Top		Bottom		Top		Bottom		Top		Bottom		Top		Bottom	
	S	A	S	A	S	A	S	A	S	A	S	A	S	A	S	A

S = Dew scale number; A = Dew amount (mm)

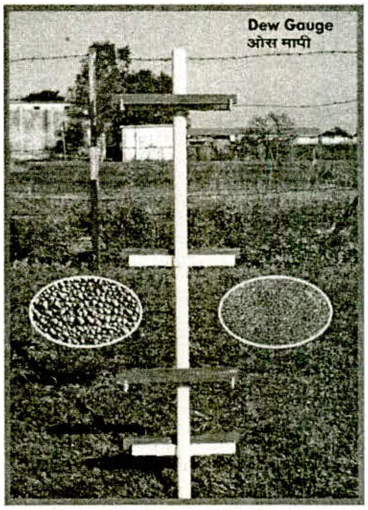


Fig 12.1. Duv Devani dew gauge

Exercise:

1. What are favourable conditions for dew formation?
2. Differentiate between dew and frost.
3. What is the significance of dew in agriculture?
4. What is period of dew observation in plain and hill areas?
5. Which chemical is used to colour the dew plates and why?
6. What will happen if dew plates are kept in open after observation?
7. What is the dew amount if the dew scale number is 4a and 4b?
8. What is the time of dew observations?
9. What are the standard dew gauge plate heights?

Practical No. 13

Title: Weather forecast, synoptic charts and weather symbols

Objective: To acquaint the students about different types of weather forecast, synoptic charts and weather symbols

Weather forecasting needs and its relevance in the field of agriculture are traditionally known for successful cultivation of crops. India Meteorological Department (IMD) is the public sector agency in the field of weather forecasting. It is operating to serve the agricultural community as a whole through different types of weather forecasting. In addition to above, the weather forecasting services for various purposes / organisations are also issued by the IMD. Weather forecast may be defined as a declaration in advance of the likelihood of occurrence of future weather event(s) or condition(s) in a specified area(s) at given period(s) on the basis of a rational study of synoptic, three-dimensional and time series data of sufficient spatial coverage of weather parameters, and analyses of correlated meteorological conditions. The positive effect of weather forecasts in agriculture is maximized if weather forecasters are aware of the farmers' requirements and farmers know how to make the most use of the forecasts that are available.

Types of weather forecasting:

The types of weather forecasting and its validity and skill are presented in the following table. All the types of weather forecasting except nowcasting are one way other useful for agricultural activities. However, their reliability decreases with increase in forecast time and decrease in area.

Type of weather forecast	Time limit / duration	skill
Nowcasting	3 to 6 hours	Fair to good
Short range	1-3 days	Fair to good
Medium range	4-10 days	Fair up to 5 days; thereafter poor
Long range	More than 10 days	Good to very good

Weather service to farmers:

A reliable short or medium range weather forecast is needed for successful on farm management such as preparation of land, seed bed, planting, choice of crops/cultivar, application fertilizer/irrigation, harvesting, post harvest storage and transportation to markets.

Later for the Agromet Advisory Services (AAS), the National Centre for Medium Range Weather Forecast (NCMRWF), New Delhi has been set up in 1988. This organization with the cooperation of ICAR and State Agricultural University (SAU) provides medium range weather forecast on every Tuesday and Friday to all 130 Agro Meteorological Field

Units (AMFU) located in all agro climatic zones of the country. These AAS bulletins are prepared in English as well as in local language. Recently IMD again took over the charge for AAS from *kharif* 2008 onwards and now it is called as "Integrated Agromet Advisory Services (IAAS). As of now, IMD is issuing quantitative district level (612 districts) weather forecast up to 5 days and the products comprise of quantitative forecasts for 7 weather parameters viz.; rainfall, maximum temperature, minimum temperatures, wind speed, wind direction, relative humidity and cloudiness. In addition, weekly cumulative rainfall forecast is also provided.

Synoptic charts:

An enormous volume of meteorological data is being collected from all over the world, continuously round the clock through various telecommunication channels. To assess and analyse the vast data, they have to be suitably presented. For this purpose, the observations are plotted on maps in standard weather codes. These maps are called "synoptic maps or charts". The surface and upper air charts are the two types of synoptic charts currently in use.

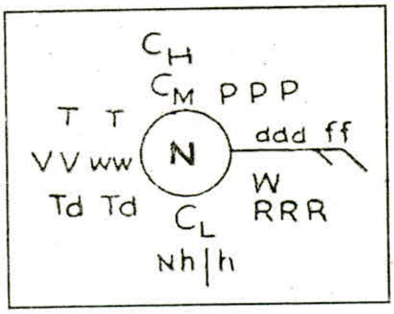
Synoptic charts display the weather conditions at a specified time over a large geographical area. The surface synoptic charts plotted for different synoptic hours (00, 03, 06, 09, 12, 15, 18, 21 UTC) depict the distribution of pressure, temperature, dew point, clouds, winds, present and past weather. In place of GMT, UTC (Universal Time Co-ordinate) is used. The upper air charts are also prepared at the standard pressure levels of the atmosphere (different heights) wherein the pressure, wind and temperature are plotted. The surface charts together with the upper air charts provide a composite three-dimensional weather picture pertaining to a given time.

The surface synoptic charts are the most used charts. It contains the maximum number of observations with the largest number of parameters plotted and often forms the base on which the pressure level charts are built up. The pattern of the pressure distribution is brought out by drawing isobars, troughs, ridges, lows, highs, depressions, cyclones, cols, fronts and discontinuities. These systems are clearly marked and labelled using appropriate symbols and colours. In synoptic charts different weather phenomena and atmospheric characters are marked with different symbols as mentioned below.

S. No	Symbols	Weather element/character/phenomenon
1	Narrow black lines	Isobars
2	Numbers at ends of isobars	Pressure values in hPa
3	Shading	Precipitation
4	Arrows	Wind direction
5	Feathers in the arrows	Wind velocity
6	Small circles with shading	Amount of clouds

Plotting of station model:

Meteorological observations are plotted according to standard station models prescribed by the World meteorological Organization (WMO). A plotting model is shown below.



Weather elements such as pressure, temperature, dew point etc. are entered in figures whereas clouds, weather phenomenon etc. are plotted as symbols at fixed positions with respect to the observing station represented by a circle on the map. Wind direction is shown as the shaft of an arrow drawn towards the station circle from the direction from which the wind blows. Wind speed is represented by bars and pennants, half barb indicating 5 knots, full barb for 10 knots and a pennant for 50 knots.

TT – Dry bulb temperature	TdTd – Dew point temperature	ww – Present weather
VV - Visibility	PPP – Barometric pressure reduced to MSL	
N – Amount of cloud	ddd – Wind direction	ff – Wind speed
Nh – Amount of high cloud	W – Past weather	RRR – Rainfall/ snowfall
C_H – Type of high cloud	C_M – Type of medium cloud	C_L – Type of low cloud
h – Height of base of low cloud	Nh – Amount of cloud reported under h-	

Note:

- Dry bulb temperature: Eg. If it is 28.4°C it has to be denoted as 284.
- Dew point temperature: Eg. If the value is 24.5°C it has to be denoted as 245.
- Present weather is indicated in red colour.

Visibility and the codes:

0-50 metres – 91	51-100 metres – 92	101-200 metres - 93	201-500 metres - 94
501-1000 metres - 95	1-5 km - 96	5-10 km - 97	10-25 km - 98
25-50 km - 99			

Barometric pressure:

- If the pressure is < 1000, it has to be depicted as it is. Eg. 977
- If the pressure is > 1000, it has to be depicted as last three decimals . Eg. 1012 as 012.

Past weather:

0 – Clear sky	1 – Partly cloudy	2 – Mainly cloudy	3 - Fog
4 - Maze	5 - Drizzle	6 - Rain	7 - Snow
8 - Thunderstorm	9 – Thunderstorm with rain		

Rainfall: The amount has to be given as rounded number not the decimals. Eg: 20.6 mm as 21

Height of base cloud: The height is to be given in km.

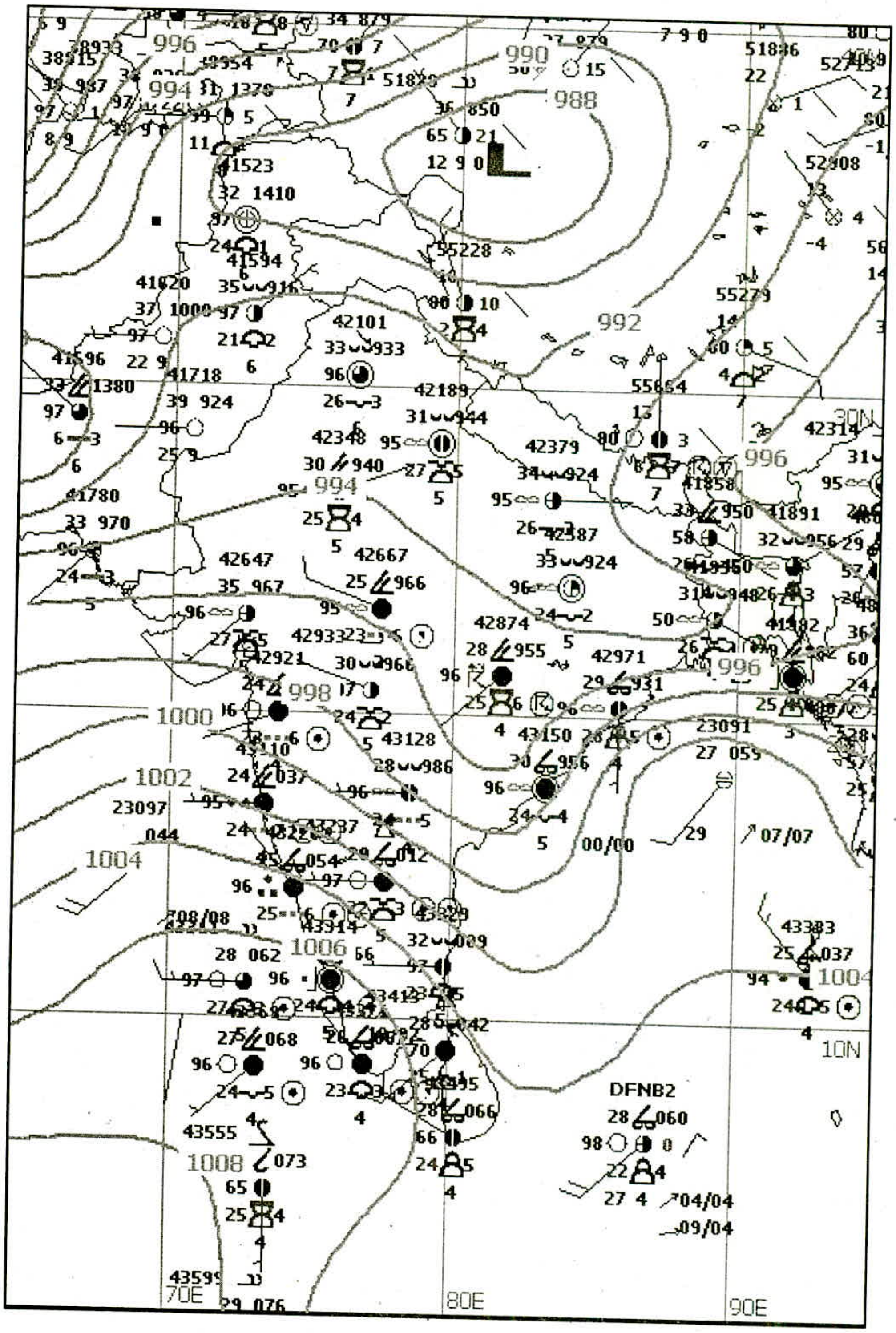


Fig. 13.1. A view of Synoptic chart

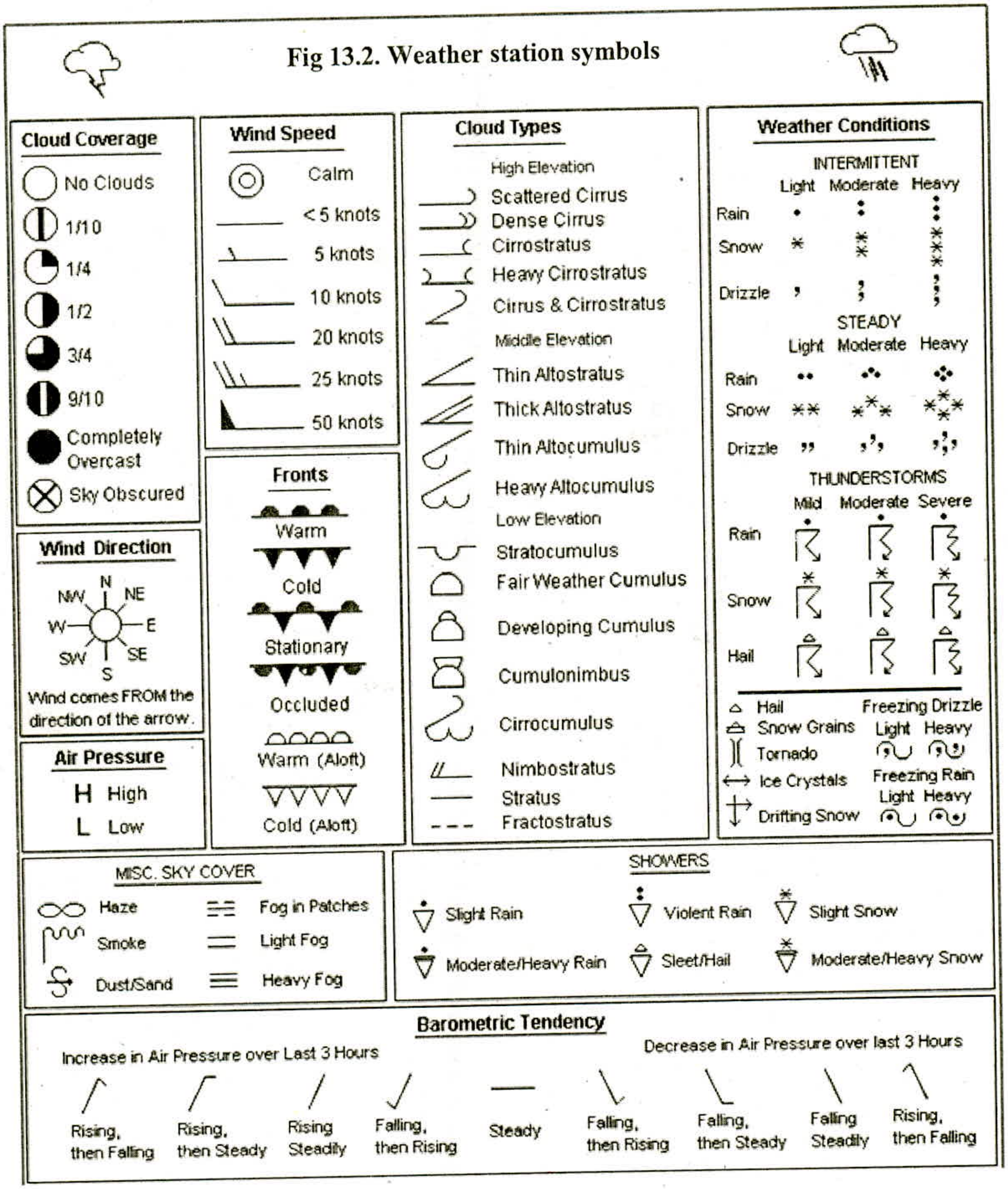
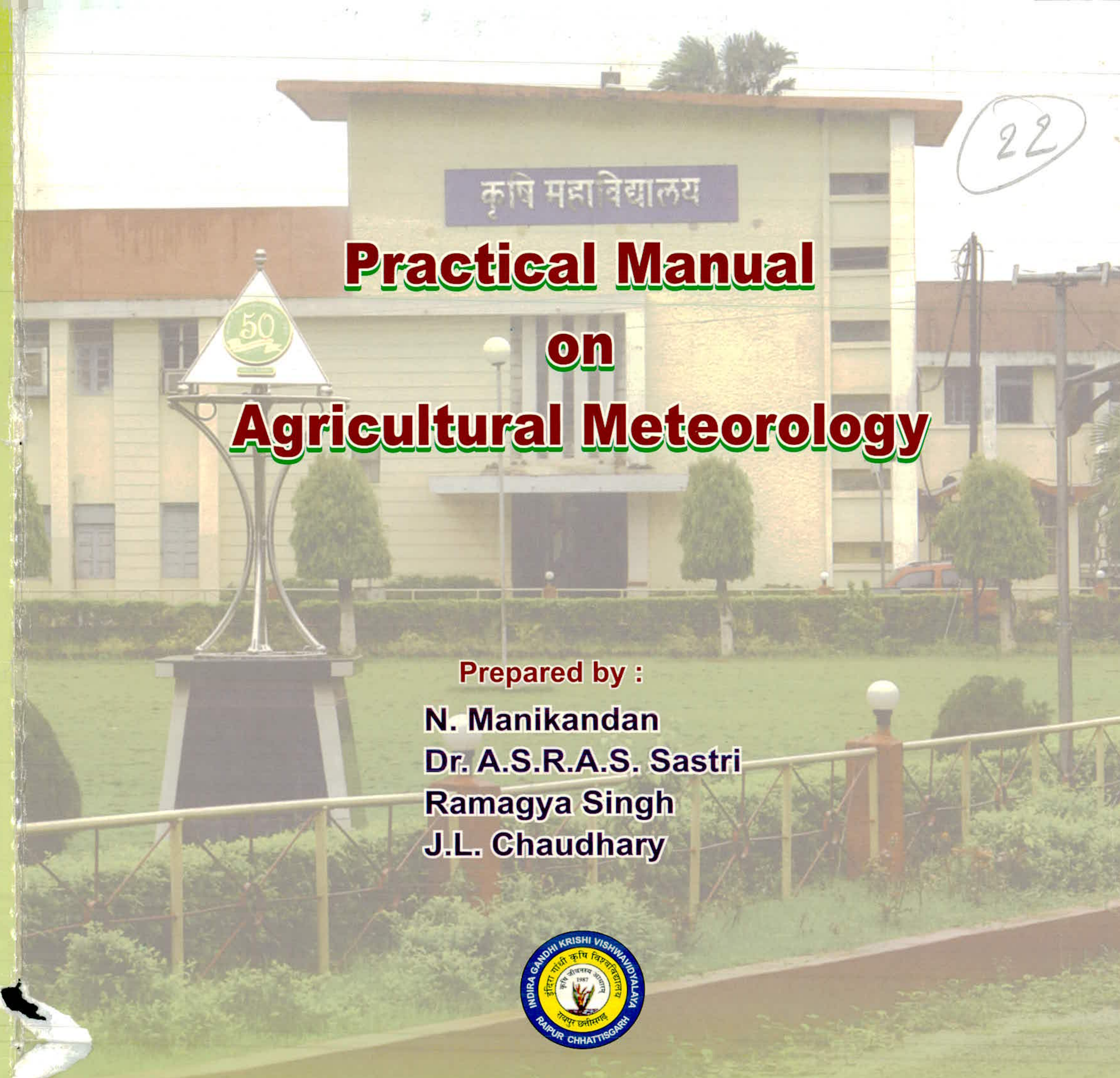


Fig 13.2. Weather station symbols

Exercise:

1. What is weather forecasting?
2. Write different types of weather forecasting and their validity.
3. Write full form of the following: AAS, AMFU, FWB, NCMRWF, IAAS.
4. Integrated Agromet Advisory services of IMD started during-------------.
5. At present IMD is issuing Medium Range Weather Forecast in --------- districts.
6. What is synoptic chart?
7. Write about different symbols used for weather parameters in synoptic charts?



22

Practical Manual on Agricultural Meteorology

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